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Identification of Contaminants of Concern

Columbia River Comprehensive Impact Assessment

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Preface

The Columbia River Comprehensive Impact Assessment (CRCIA) Project at the Pacific Northwest Laboratory (PNL)[a] is evaluating the current human and ecological risks from contaminants in the Columbia River. The risks to be studied are those attributable to past and present activities on the Hanford Site. The Hanford Site is located in southcentral Washington State near the town of Richland. Human risk from exposure to radioactive and hazardous materials will be addressed for a range of river use options. Ecological risk will be evaluated relative to the health of the current river ecosystem. The overall purpose of the project is to determine if enough contamination exists in the Columbia River to warrant cleanup actions under applicable environmental regulations.

This report documents an initial review, from a risk perspective, of the wealth of historical data concerning current or potential contamination in the Columbia River. Sampling data were examined for over 600 contaminants. A screening analysis was performed to identify those substances present in such quantities that they may pose a significant human or ecological risk. These substances will require a more detailed analysis to assess their impact on humans or the river ecosystem.

Historically, the U.S. Department of Energy (DOE) operated nine production reactors (B, C, D, DR, F, H, KE, KW, and N) along the Hanford Reach of the Columbia River. The Hanford Reach extends 85 kilometers (51 miles) downstream from Priest Rapids Dam to the head of the McNary Pool just north of the city of Richland. Eight of these reactors used single-pass cooling systems that released radionuclides, process chemicals (including chemicals that inhibited corrosion), and heated water into the Columbia River. These eight reactors were all shut down by early 1971. The N reactor, which used a closed-loop primary cooling system, operated between 1963 and 1987. It was deactivated in 1989 and is in the process of being decontaminated and decommissioned. Past operations of Hanford's processing plants also resulted in contaminated effluents, some of which have made their way to the Columbia River through the groundwater. These plants were the bismuth phosphate process plants (B and T Plants), plutonium uranium extraction plant (A Plant/PUREX), reduction and oxidation plant (S Plant/REDOX), and plutonium finishing plant (Z Plant/PFP).

The CRCIA Project is a joint activity of three government agencies at the Hanford Site: the DOE, the U.S. Environmental Protection Agency, and Washington State Department of Ecology. These agencies have signed an agreement known officially as the *Hanford Federal Facility Agreement and Consent Order* and unofficially known as the Tri-Party Agreement (TPA) (Ecology et al. 1994). Milestones have been adopted for the TPA that identify actions needed to ensure acceptable progress toward Hanford Site compliance with the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA), the *Resource Conservation and Recovery Act of 1976* (RCRA), and the *Washington State Hazardous Waste Management Act of 1976* (HWMA). The January 1994 revision to the TPA (Change Order number M-13-93-06) incorporates adjustments made to milestones designed to address cleanup strategies and achieve timely remedial decisions and actions concerning the Columbia River. This change order included the new Milestone M-13-80 that established the CRCIA Project.

(a) Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute.

The environmental quality of the Columbia River is of special interest to the public, government, and tribal governments as a source of drinking water, for crop irrigation, as ecological habitat, and for recreation. The following actions have been taken to encourage public involvement in the CRCIA Project:

- PNL has an open door policy for this project. Non-PNL individuals can visit the laboratory, interact with scientists, and observe work in progress.
- Data and documents used in the CRCIA Project are being made available to all interested parties.
- Public meetings are being conducted to obtain input to the development of work scope and technical approaches as well as to review data and work progress.

Abstract

The Columbia River Comprehensive Impact Assessment (CRCIA) Project is conducted for the U.S. Department of Energy by the Pacific Northwest Laboratory. The CRCIA Project will evaluate the current human and ecological risks from the Columbia River attributable to past and present activities on the Hanford Site. To perform a comprehensive assessment, the contaminants released from the Hanford Site must be identified. This report identifies the contaminants released and identifies those that should be considered in detailed risk analyses.

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Summary

Introduction

The Columbia River Comprehensive Impact Assessment (CRCIA) Project is conducted for the U.S. Department of Energy by the Pacific Northwest Laboratory (PNL). The CRCIA Project will evaluate the current human and ecological risks from the Columbia River attributable to past and present activities on the Hanford Site. To perform a comprehensive assessment, the contaminants released from the Hanford Site must be identified. This report identifies the contaminants released and identifies those that will be considered in detailed risk analyses.

Scope of Work

The CRCIA Project is primarily concerned with the current risks from contaminants of Hanford origin. Therefore, the most recent sampling data (from 1980 through 1994) were used to estimate the source term (amount and types of radionuclides and chemicals released to the environment from Hanford facilities) for the risk calculations. For this study, the focus is on the Columbia River water, sediment, soil, and groundwater within 150 meters (500 feet) of the Columbia River, which means a spatial focus on the Hanford 100, 300, and 1100 Areas. A multi-stage screening process was developed to prioritize these various contaminants in terms of human health risk and ecosystem risk. Each stage of the process identifies contaminants of interest to the project, based on the potential for human and ecological risk. The combined results of the total screening then compose the total list of concern.

In addition to radiological and chemical contaminants, the potential for radiation doses arising from discrete radioactive particles in the river sediment or from direct irradiation from near-river Hanford facilities is also addressed.

Although the primary concern is the current status of the Columbia River, additional consideration is given to the potential impact of contaminants currently known to be in the Hanford Site groundwater. Consideration is not given to the potential impact of contaminants that are not presently in the groundwater but which may be in soils or facilities away from the Columbia River.

Technical Approach

The first step in the approach was to collect a comprehensive list of potential contaminants. This list was prepared by examining published data, reports, and contaminant databases. The review of the available data indicated that concentrations of various radionuclides, carcinogenic chemicals, and hazardous chemicals had been measured in surface water (Columbia River, springs, and seeps), groundwater, river sediment, and near-river soil. A multi-stage screening process was developed to prioritize these various contaminants in terms of human health risk and ecosystem risk. Each stage of the process identifies contaminants of interest. The combined results of the entire screening process then compose the total list of contaminants of concern. The following screening processes were used.

Initial Screening: Initial screening eliminated the contaminants on the list that showed no detectable levels of activity or concentration.

Radionuclide Screening: Radionuclide screening is based on a scenario of exposure to an individual. The exposure includes external exposure, consumption of untreated river water, consumption of freshwater fish, and consumption of small amounts of sediment. Internal risks are estimated using the U.S. Environmental Protection Agency (EPA) indicator for ingestion, called a slope factor (EPA 1994a). This indicator represents the risk of cancer to an individual from sources other than natural background radiation per unit (e.g., picocurie) of radioactive material taken into the body. Similarly, external exposure to contaminated sediment is addressed by assuming the parameters associated with the EPA slope factor for external exposure are appropriate (EPA 1994a).

Carcinogenic Chemical Screening: The individual exposure scenario for carcinogens in river water are the same as those for radionuclides, except there is no factor for external exposure because there is no external risk from chemicals.

Toxic Chemical Screening: For hazardous, but noncarcinogenic, chemicals, the screening is based on a ratio of the estimated daily intake to the EPA chronic oral reference dose (EPA 1994a). The chronic oral reference dose is the safe dose level EPA established for specific chemicals. In other words, the chemicals in the individual exposure scenario are investigated to screen out those that are ingested in amounts below the EPA's safe levels. The exposure scenario is the same as for the radionuclides or carcinogens.

Ambient Water Quality Criteria Screening: For aquatic plants and animals (biota), the measured or surrogate (estimated) concentration of the contaminant in water is compared with the applicable EPA water quality criterion (EPA 1992). The ambient water quality criteria are those concentrations of chemicals identified by EPA as safe and protective of aquatic life.

Aquatic Biota Toxicity Screening: Limited data were available that identify the concentrations of certain chemicals that result in toxic effects to aquatic life. Where possible, the threshold concentration for fresh water at which any effect was noted was used. Where not possible, the lowest concentration lethal to 50 percent (called LC50) of small, freshwater fish (e.g., guppies, mosquito fish, rainbow trout) was used (EPA 1985). To relate these lethal effects to less significant effects, the screening used a value of 1 percent of the LC50. For a few analytes (substances for which an analysis is made) for which fish data were not available, test results for crayfish or insects were used as a surrogate.

Background Screening: During the screening process, a few radionuclides and chemicals had measurements determined to be within their respective naturally occurring background levels. Because concentrations were not above naturally occurring background, the following contaminants were eliminated from further consideration: the radionuclides beryllium-7 and potassium-40; the chemicals barium, bismuth, boron, chlorine, fluorine, lithium, silicon, silver, sulfide, titanium, vanadium, and zirconium.

Nonhazardous Screening: The screening process identified several materials as nonhazardous under environmental conditions (EPA 1991; EPA 1989). These contaminants eliminated from further consideration are aluminum, calcium, iron, magnesium, potassium, and sodium.

All of the screenings require an estimate of the contaminant's concentration in river water. Only the direct river water measurements provide this information. When direct measurements of river water were not available, surrogate water concentration was estimated. To estimate surrogate concentrations in water, certain assumptions were used.

Groundwater Contamination: Groundwater adjacent to the Columbia River can flow into the river, and Columbia River water can flow into the groundwater, depending on river flow. Therefore, concentrations of contaminants in groundwater near the river are difficult to predict, and concentrations measured near the shore differ from those measured further inland. Raymond et al. (1976) and Cline et al. (1985) report an estimated flow rate of 100 cubic feet per second (cfs) over the entire Hanford Reach. For conservatism (i.e., to provide an estimate of the resulting concentration in the river that, if incorrect, would err on the high side), the value of 100 cfs was adopted for the screening. In effect, this implies that the entire groundwater that flows from beneath Hanford to the Columbia River is contaminated to the maximum level measured.

River Sediment: Sediment within the river is both a reservoir of contaminants and a source of contamination of the river water, as the material is dissolved into or carried away by the river. An equilibrium ratio of 1:100,000 was used (i.e., the concentration of the contaminant in the sediment is assumed to be 100,000 times higher than in the Columbia River waters). This assumption is based on a limited number of samples and an empirical equation (Napier et al. 1988, p. 4.82).

Near-River Soil: Contaminants in Hanford waste sites or other sites adjacent to the Columbia River (e.g., operating facilities, spills, etc.) may pose a threat of future contamination of the river. For the purpose of screening, all contaminants are assumed to be environmentally mobile and potentially dissolvable in groundwater. Based on this assumption, the surrogate groundwater contamination is assumed to have the same concentration of contaminants as the soil. The total area of industrial activity comprises approximately 6 percent of the Hanford Site (Dirkes et al. 1994, p. 5). Because it is unreasonable to assume that all of Hanford soil is contaminated to the maximum concentration measured, an effective area of 1 percent is assumed. This means that the study assumed that 1 percent of Hanford soil is contaminated to the same extent as the highest amounts measured in Hanford soil.

Results

Analyses for more than 600 different radionuclides and chemicals have been performed on Hanford-related environmental samples. A large number of these potential contaminants have never been detected in the Hanford/Columbia River environments. Screening on the basis of potential impact on human health or the health of Columbia River ecosystems has been performed for the roughly 100 radionuclides and chemicals that have been detected in environmental samples. Several different types of screenings were employed. The results were consistent in that the same materials were identified numerous times by the various screenings. Application of the screenings for contaminants within 150 meters (500 feet) of the Columbia River yields a list of 20 contaminants of concern, plus direct irradiation. These contaminants are given in the first column of Table S.1.

Table S.1. List of Identified Contaminants of Concern[(a)]

In Columbia River, Groundwater,[(b)] Sediment, and Soil	Groundwater Plumes Away from the Columbia River[(c)]	Continued Public Interest
Antimony	Carbon Tetrachloride	Chloroform
Arochlor 1248 (PCB)	Fluoride	Cyanide
Arsenic		Iodine-129
Cesium-134		Plutonium-239/240
Cesium-137		Technetium-99
Chlordane		Trichloroethylene
Chromium[(d)]		Tritium (Hydrogen-3)
Cobalt-60/particles		Uranium
Copper		
Diesel Fuel		
Europium-152		
Europium-154		
Lead		
Manganese		
Mercury		
Nitrate/nitrite[(d)]		
Phosphate		
Silver Chloride		
Strontium-90		
Zinc		

(a) Direct irradiation is also identified as being of concern.
(b) Hanford groundwater within 150 meters (500 feet) of the Columbia River.
(c) Hanford groundwater farther than 150 meters (500 feet) from the Columbia River.
(d) These contaminants are also of concern in groundwater plumes away from the Columbia River but are not repeated in that list to avoid duplication.

Existing Hanford groundwater contamination farther than 150 meters (500 feet) (see Table 3.3) from the Columbia River was also addressed. The contaminants identified by the screening process do not appear to be currently entering the river but have the potential to do so within 10 to 200 years (Freshley and Graham 1988). Two contaminants (chromium and nitrate) in Hanford groundwater away from the river are already included in this study because they are in or near the river. Only carbon tetrachloride and fluoride were added to the list as a result of the study of groundwater away from the river. Carbon tetrachloride and fluoride have not yet been found in the river.

Although the screenings did not indicate a potential risk, several potential or existing contaminants are of particularly high public interest (third column in Table S.1). Essentially all of these are the object of ongoing evaluation by the Surface Environmental Surveillance Project (SESP) conducted by PNL at Hanford. The CRCIA Project should remain current on SESP activities and include SESP results in all project reports (see Section 8.0).

Each of the identified contaminants can be considered to have resulted from past plutonium-production operations at Hanford. The radionuclides on the list generally represent those identified with river water or Hanford Reach sediment. The radionuclides resulted from activation of materials in the old production reactors. It is likely that the cesium isotopes are related to global fallout (Dirkes et al. 1994). Most of the metals identified from Hanford groundwater or sediment can be related to various Hanford operations in the 100 Areas. The polychlorinated biphenyl (PCB), Arochlor 1248, is used in equipment and the insecticide, Chlordane, has been used at Hanford facilities, but both are still essentially associated with soil near the river. The nitrate groundwater plumes result from past Hanford operations in the 100 and 200 Areas.

The identification of the radionuclides and chemicals as being of concern to the CRCIA Project does not imply that each or all of these compounds is necessarily a prominent problem for the river or those who live downstream. The screening and selection process described in this report is a conservative (cautious) process designed to focus the resources of the project on those contaminants with potential risk.

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Glossary

100 Areas - site of the Hanford production reactors, which include B, C, D, DR, F, H, KE, KW, and N reactors.

200 Areas - site of the Hanford chemical separations plants, which include the bismuth phosphate process plants (B and T Plants), plutonium uranium extraction plant (A Plant/PUREX), and reduction and oxidation plant (S Plant/REDOX).

300 Area - site of research, development, and fuel-fabrication operations.

400 Area - site of the Fast Flux Test Facility.

600 Area - all land within the Hanford Site not occupied by the 100, 200, 300, 400, 1100, or 3000 Areas.

1100 Area - site of the warehousing, vehicle maintenance, and transportation operations center.

3000 Area - site of engineering, construction, and research and development activities.

analytes - substances for which an analysis is made.

bioconcentration factor - ratio between the radionuclide concentration in biota and the radionuclide concentration in the water in which the biota live and feed.

biota - plants and animals.

carcinogenic (chemicals) - having the property of enhancing the possibility of contracting cancer later in life following exposure.

CERCLA - *Comprehensive Environmental Response, Compensation, and Liability Act of 1980.*

Ci - abbreviation for curie.

concentration - amount of a specified substance (e.g., a radioactive element) in a unit amount of another substance (e.g., river water, milk).

conceptual model - any representation of a biological or mechanical process.

CRCIA - Columbia River Comprehensive Impact Assessment.

curie - unit of radioactivity corresponding to 3.7×10^{10} (37 billion) disintegrations per second (abbreviated Ci), 1 curie = 3.7×10^{10} becquerel.

DOE - U.S. Department of Energy.

Ecology - Washington State Department of Ecology.

EIS - environmental impact statement.

EPA - U.S. Environmental Protection Agency.

exposure - process of coming into contact with environmental materials.

internal exposure - contact with materials taken into the body through inhalation or ingestion.

external exposure - contact with materials on the outside of the body, as from submersion in water or immersion in air.

gross beta - total activity of beta-emitting radionuclides that are not distinguished separately by instrumentation or radiochemical analyses.

half-life - time required for an initial number of radioactive atoms to be reduced to half that number by radiological transformations.

Hanford Reach - stretch of the Columbia River downstream of Priest Rapids Dam and upstream of the confluence of the Yakima and Columbia Rivers.

hazardous (chemicals) - having the property of being toxic, at some level of exposure. Generally used to differentiate from carcinogenic.

HEIS - Hanford Environmental Information System. An electronic database that consolidates the data gathered during environmental monitoring and restoration of the Hanford Site.

HWMA - *Washington State Hazardous Waste Management Act of 1976*.

IRIS - Integrated Risk Information System, an EPA database that provides data on chronic health hazards (reference dose values), carcinogenicity (unit risk factors or slope factors), EPA regulatory actions, supplementary data, and a bibliography for each listed chemical.

irradiation - exposure of an object to ionizing radiation.

isotope - one of two or more atoms having the same atomic number but different mass.

LFI - limited field investigation conducted as part of Tri-Party Agreement activities to identify those Hanford waste sites that are recommended to remain as candidates for interim remedial measures.

MEPAS - Multimedia Environmental Pollutant Assessment System, a computer code that can be used to estimate the transport and fate of environmental pollutants.

model - conceptual representation of a physical/biological process. The representation may be graphical or a set of mathematical equations that simulate the process being modeled. See also conceptual model.

natural uranium - naturally occurring mixture of uranium (0.7 percent uranium-235 and 99.3 percent uranium-238).

NPL - national priorities list.

operable unit - term used to identify specific areas designated for cleanup.

PCB - polychlorinated biphenyl.

picocurie - one-millionth of a millionth curie (10^{-12}).

plume - definitive volume of air, water, or soil containing contaminants released from a contaminant source.

PNL - Pacific Northwest Laboratory.

production reactor - facility (B, C, D, DR, F, H, KE, KW, or N reactors) in which uranium or other fuel was irradiated with neutrons to produce radioactive materials. Used primarily at Hanford to produce plutonium for weapons; used also for research. Synonymous with "reactor."

radioactivity - spontaneous emission of radiation (alpha, beta, gamma rays, and/or neutrons) by some isotopes as they transform into other isotopes.

radionuclide - radioactive isotope of an element.

RCRA - *Resource Conservation and Recovery Act of 1976*.

reactor - see production reactor.

reference dose - EPA's estimate of the smallest daily intake of a hazardous material that first leads to deleterious health effects.

RI/FS - remedial investigation/feasibility study.

SARA - *Superfund Amendments and Reauthorization Act*.

seeps - very small springs of groundwater.

SESP - Surface Environmental Surveillance Project.

slope factor - EPA's value which represents the lifetime excess cancer risk per unit of intake.

source term - amount of radioactivity (curies) of a radionuclide or amount of a chemical released to the environment from a facility over a given time.

springs - source of water issuing from the ground.

SST - single-shell tank.

stack - tall chimney that was the primary release point of exhaust air from a reactor or separations plant building.

surrogate (measurement) - estimated substitute measurement used when actual measurements not available.

TPA - Tri-Party Agreement (officially, *Hanford Federal Facility Agreement and Consent Order*).

TSD - treatment, storage, and disposal facilities or units at Hanford.

TWRS - tank waste remediation system.

UST - underground storage tank.

VOC - volatile organic compounds.

Contents

Figures

Tables

1.0 Introduction

Pacific Northwest Laboratory (PNL) is conducting a comprehensive assessment of the Columbia River. The purpose of the Columbia River Comprehensive Impact Assessment (CRCIA) Project is to evaluate the current human and ecological risk from radioactive and other hazardous materials in the Columbia River as a result of past and present activities at the Hanford Site near Richland, Washington. Many thousands of radionuclides and hazardous chemicals[a] have been generated or used at Hanford over the past five decades, only some of which may be of current concern for human or ecological risk. The intent of this report is to focus the resources of the project on the contaminants of greatest concern.

1.1 Background

The Hanford Site in southcentral Washington State was acquired by the federal government in 1943 and was dedicated for many years to the production of plutonium for national defense and the management of resulting wastes. The production of nuclear materials for weapons ended at Hanford in 1987. With the shutdown of the production facilities, missions were diversified to include research and development in the areas of energy, waste management, and environmental restoration.

The Hanford Site is about 1,450 square kilometers (560 square miles) of semi-arid shrub-steppe located just north of the confluence of the Yakima River with the Columbia River (Figure 1.1). Approximately 6 percent of the Hanford Site has been used for operations in the following areas:

- 100-B/C, 100-D, 100-F, 100-H, 100-K, and 100-N Areas, which lie along the Columbia River in the northern portion of the Hanford Site, are the sites of the nine Hanford plutonium production reactors (now shut down)

- 200-East and 200-West Areas, which lie in the center of the Hanford Site, are the sites of the chemical reprocessing facilities and low-level- and high-level-waste management facilities

- 300 Area, near the southern border of the Hanford Site, is the site used for nuclear fuel manufacturing and research facilities

- 400 Area, between the 200 and 300 Areas, is the site of the Fast Flux Test Facility

- 1100 Area and 3000 Area, a corridor northwest of the city of Richland, are sites used for warehousing, vehicle maintenance, transportation operations center, construction, engineering, and research and development activities.

(a) In this report, organic chemicals, inorganic chemicals, ions, elements, and other chemical compounds are simply referred to as chemicals.

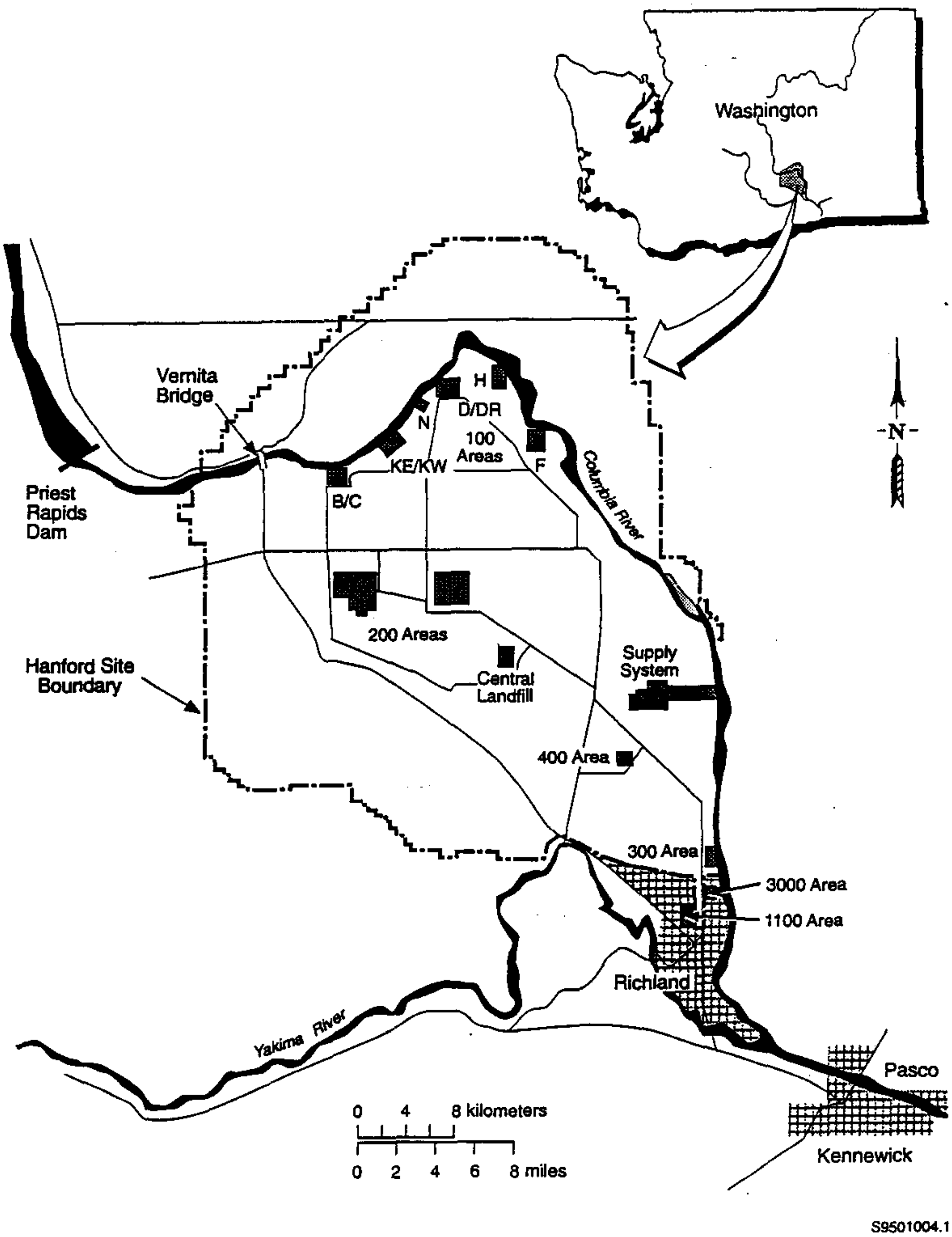

Figure 1.1. Map of the Hanford Site

Fifty-one miles of the Columbia River, known as the Hanford Reach, flows through or borders the Hanford Site. The Hanford Reach is roughly from Priest Rapids Dam to the confluence of the Yakima River with the Columbia River. This stretch of the river offers a unique example of the river and riparian (riverside) ecologies that characterized the Columbia Basin ecosystem prior to construction of hydroelectric dams on the river. The Hanford Reach comprises the last unimpounded stretch of the Columbia River in the United States. Nearly 60 percent of the Columbia River's native wild stock of fall chinook salmon spawn in the reach (National Parks Service 1992). River water is used downstream from the Hanford Site by Washington and Oregon residents for drinking water, agriculture, industry, transportation, and recreation. The riverbanks and islands provide habitat for several species of threatened or endangered plants (e.g., Columbia milkvetch and Hoover's desert parsley) and animals (e.g., bald eagles) (National Parks Service 1992).

Plutonium production operations in the 100 Areas historically have resulted in releases of contaminants directly to the Columbia River and left extensive contamination in some areas of the surface soil, subsurface soil, and groundwater. Contamination reaches the river through groundwater seepage.

Facilities in the 200 Areas were built to process irradiated fuel from the production reactors. The subsequent operation of these facilities resulted in the storage, disposal, and some releases of radioactive and nonradioactive wastes to the environment. Contamination exists in the surface, subsurface, and groundwater in the 200 Areas. Contaminated groundwater has moved out of the operating areas into areas adjoining the operating areas.

The 300 Area is the site of former reactor fuel processing activities. The 300 Area is also the location of nuclear research and development facilities serving the Hanford Site. Wastes in the 300 Area have resulted from the fuel fabrication process and various research activities. Contamination exists in the surface, subsurface, and groundwater.

The 1100 Area just north of Richland serves as the warehousing, vehicle maintenance, and transportation operations center for the Hanford Site. Wastes present result primarily from disposal of batteries, paints and solvents, and antifreeze. Immediately adjacent to the 1100 Area is the 3000 Area, home of Hanford Site engineering, construction, and research and development activities. Minor chemical contamination from paints, solvents, and related activities is also present here.

The 600 Area is defined to include all land within the Hanford Site not occupied by the 100, 200, 300, 400, 1100, and 3000 Areas. Lands uses within the 600 Area include a 41-hectare (100-acre) tract subleased from the state of Washington for the disposal of commercial low-level nuclear waste and nuclear power facilities operated by the Washington Public Power Supply System. Most contamination in the 600 Area reaches the Columbia River by groundwater.

1.2 Purpose

This report documents an initial review of the abundance of historical data concerning contamination, current or potential, of the Columbia River. The initial review focuses on the availability of key data for particular contaminants at specific locations in specific media. The result is a list of contaminants of concern for current human or ecological risk. The list will help focus the effects of health risk assessments because the contaminants on this list are those with the highest risk levels.

The list of contaminants of concern will also be used to help define future sampling requirements to obtain current data for use in the CRCIA Project.

1.3 Scope

This study is primarily concerned with the current risks from contaminants of Hanford origin. Therefore, the most recent sampling data are used to provide the applicable source term for the risk calculations. For this study, the focus is on the Columbia River water, sediment, soil, and groundwater within 150 meters (500 feet) of the Columbia River, which means a spatial focus on the Hanford 100, 300, and 1100 Areas. A multi-stage screening process was developed to prioritize these various sources in terms of human health risk and ecosystem risk. Each stage of the process identifies pollutants of interest. The combined results of the total screening then compose the total list of concern.

The potential is also addressed for radiation doses arising from discrete radioactive particles in the river sediment or from direct irradiation from near-river Hanford facilities.

Although the primary concern is the current status of the Columbia River, additional consideration is given to the potential for future impact by contaminants currently present in the Hanford Site groundwater. Consideration is not given to the potential impact of contaminants that may be in soils or facilities away from the Columbia River but that are not presently in the groundwater.

1.4 Preview of Report

The references used as data sources are annotated in Section 2.0 of this report. A composite list of radionuclides and chemicals identified as being present in environmental samples is presented in Section 3.0. The numerical approach to screening the several hundred analytes into a short list of contaminants of concern is presented in Section 4.0. The results of the screening process are listed in Section 4.3. A discussion of discrete radioactive particles in the sediment of the Columbia River shoreline and islands is given in Section 5.0. Section 6.0 addresses direct gamma irradiation from Hanford facilities located adjacent to the river. Section 7.0 addresses existing and potential future contaminants from groundwater sources away from the river. Contaminants of possible continued public interest are acknowledged in Section 8.0. The overall conclusions, listed as the contaminants of concern, are given in Section 9.0. Supporting material is made available in the appendices at the end of the report.

2.0 Data Sources

An annotated bibliography of the sources used to identify the analytes sampled in environmental media are provided in this section. No single document or electronic database was available that covered the entire scope of contaminants for this research. Baseline efforts similar to the scope of our task were done in a project by Fowler et al. (1993). However, because that project covered all exposure pathways and numerous U.S. Department of Energy (DOE) sites, and identified only the presence of contaminants and not their concentrations, it is not directly applicable or as comprehensive as required for this task.

The CRCIA Project developed a compendium of existing data on Columbia River contamination (Eslinger et al. 1994). The compendium is a large bibliography of Hanford and non-Hanford sources that potentially contain relevant environmental monitoring information. This compendium was used as a starting point for data information.

This study is primarily concerned with the current risks from contaminants of Hanford origin. Therefore, the most recent sampling data provide the source term for the risk calculations. A secondary concern of this study is the potential for future contamination of the river from Hanford facilities away from the river. Summary information related to existing groundwater plumes that are farther than 150 meters (500 feet) from the Columbia River on the Hanford Site was also reviewed.

To understand some of the key terms in the bibliography, it is necessary to know that the radioactive, hazardous chemical, and mixed wastes are found in various individual waste sites, referred to as waste management units, located throughout the Hanford Site. These individual waste management units include past practice sites; surplus facilities; and treatment, storage, and disposal (TSD) facilities. Past practice sites and TSD facilities may take the form of spills, cribs, ditches, ponds, tanks, trenches, landfills, burial grounds, pits, French drains, and other means of intentional or unintentional disposal. Surplus facilities include contaminated buildings, exhaust stacks, and underground transfer lines. The individual waste management units are organized into "operable units" based on geographic proximity or similarity of waste disposal history.

The following annotated bibliography summarizes the sampling data sources and primary references used in the compilation of the monitoring data. The complete reference, sampling purpose, sampling time frame, media sampled, as well as supplementary comments, are provided. Documents of specific types are listed together, in alphabetical order. Appendix A presents a complete list of radionuclides and chemicals evaluated at Hanford.

2.1 General References

Dirkes, R. L. 1993. *Columbia River Monitoring: Distribution of Tritium in Columbia River Water at the Richland Pumphouse*. PNL-8531, Pacific Northwest Laboratory, Richland, Washington.

This document reports the results of a special investigation conducted by the PNL Surface Environmental Surveillance Project. Supplemental monitoring of tritium (hydrogen-3) in the Columbia River was conducted in the summers of 1987 and 1988. The purpose of the monitoring was to provide information related to the dispersion and distribution of Hanford-originating contaminants entering the river through the seepage of groundwater along the Hanford Site.

Dirkes, R. L. 1994. *Summary of Radiological Monitoring of Columbia River Water along the Hanford Reach, 1980 through 1989*. PNL-9223, Pacific Northwest Laboratory, Richland, Washington.

A portion of PNL's Surface Environmental Surveillance Project is involved with monitoring the Columbia River. This document summarizes the river water monitoring activities of the Columbia River monitoring program during the 1980s. Routine and special monitoring projects and radiological and chemical constituents are reviewed. This report summarizes the information presented in the annual environmental reports.

Dirkes, R. L., G. W. Patton, and B. L. Tiller. 1993. *Columbia River Monitoring: Summary of Chemical Monitoring Along Cross Sections at Vernita Bridge and Richland*. PNL-8654, Pacific Northwest Laboratory, Richland, Washington.

Chemical monitoring was performed by PNL's Surface Environmental Surveillance Project at the Vernita Bridge and the Richland Pumphouse. Potential Hanford-originating chemicals of interest were selected for sampling; these included volatile organic compounds (VOCs), metals, and anions. Monthly samples were taken from August 1991 to December 1991. The sample frequency was reduced to quarterly during calendar year 1992. The monitoring results were benchmarked with those of the United States Geological Survey monitoring program, and no variants were found.

DOE - U.S. Department of Energy. 1992a. *Sampling and Analysis of 100 Area Springs*. DOE/RL-92-12, Rev. 1, U.S. Department of Energy, Richland, Washington.

This document provides validated monitoring data from the sampling of the Columbia River, seeps, springs, and sediment adjacent to the Hanford 100 Areas National Priorities List Site. The data were published as part of a Tri-Party Agreement milestone to evaluate how the contaminated seeps and springs impact the Columbia River. An assessment of the data is included. Samples were collected in September and October 1991 during the normal low-flow period of the Columbia River. Twenty-six locations were sampled along a 37-kilometer (22-mile) stretch of the river, ranging from just upstream of the 100-B/C Area water intake to the old Hanford townsite.

DOE - U.S. Department of Energy. 1992b. *Hanford Site Groundwater Background*. DOE/RL-92-23, U.S. Department of Energy, Richland, Washington.

This report is a preliminary evaluation of data and information related to the natural composition of groundwater in the unconfined aquifer system beneath the Hanford Site. This information is to be used as a baseline for distinguishing the presence and significance of contamination in the groundwater. The relevant part of the aquifer evaluated extended from the surface waters that potentially recharge the aquifer to the uppermost portion of the underlying confined aquifer. Surface waters were found, in general, to have lower concentrations of constituents than the springs, unconfined groundwater, and confined groundwater. The provisional background threshold levels of background constituent concentrations in groundwater that are indicated in this report are likely to be conservatively low.

DOE - U.S. Department of Energy. 1994a. *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*. DOE/RL-92-24, Rev. 2, Vol. 1 of 2, U.S. Department of Energy, Richland, Washington.

This document was written to support environmental restoration, waste management, and facilities operations activities at Hanford. The background composition of Hanford Site soil is characterized for the purposes of identifying soil contamination and as a baseline in risk assessment processes used to determine soil cleanup and treatment levels. The compositions of naturally occurring soil in the zone above the groundwater level have been determined for nonradioactive inorganic and organic analytes and related physical properties. The range of inorganic and organic analytes that can be expected in Hanford Site background soil is evaluated. The highest measured background concentrations occur in three volumetrically minor soil types, the most important of which is topsoil adjacent to the Columbia River, which are rich in organic carbon. The chemical composition of more than 170 soil samples from 22 places on the Hanford Site and 3 places adjoining the Hanford Site was determined for inorganic analytes in accordance with EPA protocols. Twelve of the samples were analyzed for volatile and semivolatile organic chemicals, as well as for pesticides and polychlorinated biphenyls (PCB). Samples were collected from September through November 1991.

DOE - U.S. Department of Energy. 1994b. *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities*. DOE/RL-93-88, Rev. 0, U.S. Department of Energy, Richland, Washington.

This report is an annual hydrologic evaluation of 20 RCRA groundwater monitoring projects and one nonhazardous waste facility at the Hanford Site. The interpretation of groundwater data collected at 30 waste management units between October 1992 and September 1993 is included. Also, recent groundwater quality evaluations for the 100 and 300 Areas and the entire Hanford Site are described. Widespread contaminants include nitrate, chromium, carbon tetrachloride, tritium (hydrogen-3), and other radionuclides.

Eslinger, P. W., L. R. Huesties, A. D. Maughan, T. B. Miley, and W. H. Walters. 1994. *Data Compendium for the Columbia River Impact Assessment*. PNL-9785, Pacific Northwest Laboratory, Richland, Washington.

This document provides a bibliography of sources of existing data on Columbia River contamination. Approximately 4,500 documents and 13 major databases are listed that potentially contain information about contaminants in the Columbia River due to Hanford activities. The bibliography was further refined to highlight 60 key documents that contain data or describe analyses important in evaluating the health of the Columbia River. The work was performed to meet the Tri-Party Agreement milestone number M-13-80.

Ford, B. H. 1993. *Groundwater Field Characterization Report for the 200 Aggregate Area Management Study*. WHC-SD-EN-TI-020, Westinghouse Hanford Company, Richland, Washington.

This report provides contaminant plume maps for the unconfined aquifer of the 200 East and 200 West groundwater aggregate areas. Data deficiencies are identified with recommendations for additional sampling and well drilling. Individual plumes are identified for arsenic, chromium, cyanide, fluoride, nitrate, carbon tetrachloride, chloroform, trichloroethylene, tritium (hydrogen-3), gross beta, cobalt-60, strontium-90, technetium-99, iodine-129, cesium-137, gross alpha, uranium, and plutonium.

Fowler, K. M., K. B. Miller, M. O. Hogan, and J. F. Donaghue. 1993. *Risk-Based Standards Chemicals of Interest Database Documentation*. DRAFT. Prepared for the U.S. Department of Energy by the Pacific Northwest Laboratory, Richland, Washington.

A comprehensive set of risk-based standards are needed by the U.S. DOE to conduct its waste management, environmental restoration, and decontamination and decommissioning activities. The first step in developing the standards was to gather information on hazardous and radioactive substances that are found as contaminants or that are stored at DOE facilities. Twenty-six DOE sites were surveyed for substances that are generated, used, or present. Sources of information included Superfund Amendments and Reauthorization Act (SARA) Title III reports, remedial investigation/feasibility study reports, and other miscellaneous sources. The radionuclide and chemical names and media type in which they were found (i.e., air, groundwater, sediment, soil, surface water, tank wastes, and not specified/available) are indicated, but no quantitative sampling results are provided in this document. A total of 326 radionuclides and chemicals were identified for the Hanford Site.

Hartman, M. J., and K. A. Lindsey. 1993. *Hydrogeology of the 100-N Area, Hanford Site, Washington*. WHC-SD-EN-EV-027, Westinghouse Hanford Company, Richland, Washington.

The report primarily describes the hydrologic units beneath the 100-N Area. It includes descriptions of primary contaminants of interest, including strontium-90 and tritium (hydrogen-3) associated with the liquid waste disposal sites, sulfate and sodium, and petroleum products associated with leaks and spills. A total of eight petroleum (diesel oil) spills are documented between 1966 and 1988. Following the 1966 leak, an interceptor trench was built to collect migrating diesel oil, where it was periodically burned. A significant amount of free petroleum apparently remains in the zone above groundwater level; as much as 45 centimeters (1.5 feet) of petroleum product has been observed floating on top of the water in some of the monitoring wells. The petroleum seems to appear on the water table following periods of recharge to the aquifer.

Law, A. G. 1990. *Status of Groundwater in the 1100 Area*. Correspondence No. 8900604B R4, Westinghouse Hanford Company, Richland, Washington.

This document provides the quarterly results from the Westinghouse Hanford Company operational groundwater monitoring program for five wells installed in the vicinity of the 1100 Area. Results for approximately 380 analytes are presented; all are essentially undetected or at background levels.

Peterson, R. E., and V. G. Johnson. 1992. *Riverbank Seepage of Groundwater Along the 100 Areas Shoreline, Hanford Site*. WHC-EP-0609, Westinghouse Hanford Company, Richland, Washington.

Data were obtained during environmental surveillance activities and remedial investigations to characterize the influence of contaminated groundwater on the Columbia River. Radionuclides and metals in the seepage, sediment associated with the seepage, and near-shore Columbia River water were sampled. Samples collected in September and October of 1991 are compared with data collected in 1984 and 1988, as well as nearby groundwater data.

Rowley, C. A. 1993. *100-N Area Underground Storage Tank Closures*. WHC-SD-EN-TI-136, Westinghouse Hanford Company, Richland, Washington.

This report describes removal/characterization actions concerning underground petroleum storage tanks in the 100-N Area undertaken from 1990 through 1992. Instances of leaks from underground connections are noted. No groundwater contamination was found resulting from these tanks.

Weiss, S. G. 1993. *100 Area Columbia River Sediment Sampling*. WHC-SD-EN-TI-198, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

To determine whether radiological and chemical contaminants are present in the Columbia River, 44 sediment samples were collected from 28 locations in the Hanford Reach in the fall of 1992. The sand-sized and smaller sediment samples were analyzed for metals and radionuclides from the near-shore and shoreline. Three of the sample locations were upriver from Hanford. Sediment was collected at depths of 0-15 centimeters (0-6 inches) and 30-60 centimeters (12-24 inches) below the surface. Contamination from arsenic, chromium, copper, lead, and zinc was found. The arsenic, lead, and zinc contamination may not be of Hanford origin. Cesium-137 and europium-152 were the most frequently detected radionuclides.

Wells, D. 1994. *Radioactivity in Columbia River Sediments and their Health Effects*. Special Report, Washington State Department of Health, Olympia, Washington.

This document addresses the current human health effects of artificial radioactivity in the Columbia River sediment. The Columbia River sediment data from the early 1960s to the present were provided by state agencies, federal agencies, and academic researchers. The sediment samples were collected from the Hanford area to the estuaries and coastlines of Oregon and Washington. Samples include surface sediment and deeper sediment behind the dams of the lower Columbia River. Ecological risks were not evaluated; nor were the human health risks from sediment contaminated with radioactive materials entering the Columbia River at riverbank seeps and springs.

2.2 Hanford Environmental Information System

DOE - U.S. Department of Energy. 1994c. *HEIS - Hanford Environmental Information System*. For documentation supporting the HEIS database, see DOE/RL-93-24, 9 volumes, U.S. Department of Energy, Richland, Washington. Queried: August 24, 1994.

The Hanford Environmental Information System (HEIS) is an electronic database that consolidates the data gathered during environmental monitoring and restoration of the Hanford Site. Data stored in HEIS are collected under several regulatory programs. The basis of HEIS is individual sample data for air, biota, groundwater, soil, sediment, surface water, and miscellaneous materials. The HEIS system was queried for information about maximum contaminant concentrations in groundwater within 150 meters (500 feet) of the Columbia River.

2.3 Remedial Investigation/Feasibility Studies

The EPA is the lead regulatory agency for the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA). Under CERCLA, a specific process has been established to identify potentially hazardous sites, characterize site contamination, assess treatment technologies, and then design and construct the appropriate treatment facilities. The remedial investigation/feasibility study (RI/FS) portion of the process defined in CERCLA requires determining the nature and extent of the threat posed by a release of hazardous substances to the environment and evaluating proposed remedies. The RI/FS studies which contributed information to the CRCIA Project are:

DOE - U.S. Department of Energy. 1990a. *Remedial Investigation/Feasibility Study Work Plan for the 300-FF-5 Operable Unit, Hanford Site, Richland, Washington*. DOE/RL 89-14, U.S. Department of Energy, Richland, Washington.

The 300-FF-5 operable unit consists of the groundwater aquifer beneath the 300-FF-1, 300-FF-2, and 300-FF-3 source operable units and adjacent areas defined by the extent of the groundwater contamination. The scope of the 300-FF-5 operable unit RI/FS focuses on groundwater, soil, surface water/ sediment and aquatic biota and considers all contaminant sources in the 300 Area that contribute to the existing groundwater contamination beneath the 300 Area and the surrounding environment. The sample data upon which the RI/FS is based appear to have been taken in the mid-1980s. Groundwater monitoring for metals began in 1985.

DOE - U.S. Department of Energy. 1990b. *Remedial Investigation/Feasibility Study Work Plan for the 300-FF-1 Operable Unit, Hanford Site, Richland, Washington*. DOE/RL 89-31, U.S. Department of Energy, Richland, Washington.

The purpose of the 300-FF-1 operable unit remedial investigation was to provide sufficient information to conduct the feasibility study by determining the nature and extent of the threat to public health and the environment posed by releases of hazardous substances from 300-FF-1, a process liquid operable unit that contains all the liquid waste disposal facilities within the 300 Area. Hazardous and radioactive materials from this operable unit contribute to groundwater contamination. Soil sampling data are provided for radionuclides, inorganics, and an extensive list of organics. Monitoring of groundwater analytes was more limited.

2.4 Hanford Site Environmental Reports

Every year, beginning in 1957, a report is prepared that summarizes environmental data, which characterize the Hanford Site environmental management performance and demonstrate compliance status. These reports summarize the activities and results of monitoring by the Surface Environmental Surveillance Project. In recent years, data have been provided in separate volumes. Annual reports used in the development of this project include the following:

Bisping, L. E. 1994. *Hanford Site Environmental Data for Calendar Year 1993 - Surface and Columbia River*. PNL-9824, Pacific Northwest Laboratory, Richland, Washington.

Bisping, L. E., and R. K. Woodruff. 1993. *Hanford Site Environmental Data for Calendar Year 1992 - Surface and Columbia River*. PNL-8683, Pacific Northwest Laboratory, Richland, Washington.

Bisping, L. E. 1992. *Hanford Site Environmental Data 1991 - Surface and Columbia River*. PNL-8149, Pacific Northwest Laboratory, Richland, Washington.

Dirkes, R. L., R. W. Hanf, R. K. Woodruff, and R. E. Lundgren. 1994. *Hanford Site Environmental Report for Calendar Year 1993*. PNL-9823, Pacific Northwest Laboratory, Richland, Washington.

Woodruff, R. K., R. W. Hanf, and R. E. Lundgren. 1993. *Hanford Site Environmental Report for Calendar Year 1992*. PNL-8682, Pacific Northwest Laboratory, Richland, Washington.

Woodruff, R. K., R. W. Hanf, and R. E. Lundgren. 1992. *Hanford Site Environmental Report for Calendar Year 1991*. PNL-8148, Pacific Northwest Laboratory, Richland, Washington.

2.5 Limited Field Investigations

Limited Field Investigations (LFIs) are conducted as part of Tri-Party Agreement activities to identify those Hanford waste sites that are recommended to remain as candidates for interim remedial measures. The assessments include consideration of whether contaminant concentrations pose an unacceptable risk that warrants action through interim remedial measures.

Each LFI is conducted on a single Hanford operable unit (e.g., operable unit 100-HR-3). Operable unit is the term used to identify specific areas designated for cleanup. The number and first letter in the operable unit name indicate the location of the operable unit; operable unit 100-HR-3 is in the 100-H Area. Many of the column headings in Appendix A correspond to the operable unit name.

The LFI reports annotated in this section are available to the public. The following list of LFI reports are those identified by Westinghouse Hanford Company's Environmental Data Management Control as undergoing final review and so not yet available to the public:

Operable Unit	Document Number
100-FR-3	DOE\RL-93-83
100-FR-1	DOE\RL-93-02
100-NR-2	DOE\RL-93-81
100-BC-2	DOE\RL-94-42
100-HR-2	DOE\RL-94-53

DOE - U.S. Department of Energy. 1994d. *Limited Field Investigation Report for the 100-BC-1 Operable Unit*. DOE/RL-93-06, U.S. Department of Energy, Richland, Washington.

This study was initiated to characterize the liquid and sludge at disposal sites associated with the B Reactor in the 100-BC Area. Groundwater sampling data are contained in the LFI, 100-BC-5 (see below). Surface water and sediment sampling are not applicable to the 100-BC-1 area. Media were sampled for VOCs, semivolatiles, inorganics, metals, PCBs, pesticides, radionuclides, and physical properties. Sampling data were collected from April 1992 through July 1992.

DOE - U.S. Department of Energy. 1993a. *Limited Field Investigation Report for the 100-BC-5 Operable Unit*. DOE/RL-93-37, Draft A, U.S. Department of Energy, Richland, Washington.

This study was initiated to further characterize the groundwater contamination in the 100-BC Area. Groundwater, surface water, sediment, and soil sampling data are provided. Volatile constituent concentrations were of primary interest, but the media were also sampled for radionuclides, organics, inorganics, and physical properties. The LFI groundwater sampling data are reported for July 1992, October 1992, and January 1993.

DOE - U.S. Department of Energy. 1993b. *Limited Field Investigation Report for the 100-DR-1 Operable Unit*. DOE/RL-93-29, Draft A, U.S. Department of Energy, Richland, Washington.

The purpose of this study was to characterize the waste facility sites associated with the D Reactor and the water retention basin systems for both the D and DR Reactors and in the 100-DR Area. Soil sampling results are reported. Groundwater sampling data for this same region are contained in the LFI, 100-HR-3 (see below). Media were sampled for VOCs, semivolatiles, inorganics, metals, PCBs, pesticides, radionuclides, specific anions, hexavalent chromium, and physical properties. Samples were collected in March 1993.

DOE - U.S. Department of Energy. 1993c. *Limited Field Investigation Report for the 100-HR-1 Operable Unit*. DOE/RL-93-51, Draft A, U.S. Department of Energy, Richland, Washington.

This study was initiated to characterize the waste units associated with facility sites supporting the H Reactor in the 100-H Area. This document provides sludge, sediment, and soil sampling data. Groundwater sampling data are contained in the LFI, 100-HR-3 (see below). Media were sampled for VOCs, semivolatiles, inorganics, metals, PCBs, pesticides, radionuclides, and physical properties. The media were sampled from December 1991 through August 1992.

DOE - U.S. Department of Energy. 1993d. *Limited Field Investigation Report for the 100-HR-3 Operable Unit*. DOE/RL-93-43, Draft A, U.S. Department of Energy, Richland, Washington.

This study was initiated to further characterize the groundwater contamination in the 100-HR-3 operable unit, which is inclusive of three sub-areas: 100-D, 100-H, and the 600 Area between the D and H Reactor areas. This document provides groundwater, sediment and soil sampling data for radionuclides, volatile and semivolatile organic compounds, inorganics, and pesticides. Media were sampled from May 1992 through March 1993.

DOE - U.S. Department of Energy. 1994e. *Limited Field Investigation Report for the 100-KR-1 Operable Unit*. DOE/RL-93-78, Draft A, U.S. Department of Energy, Richland, Washington.

This document provides soil sampling data. Groundwater sampling data are contained in the LFI, 100-KR-4 (see below). Surface water and sediment sampling are not applicable to the 100-KR-1 operable unit. Media were sampled for VOCs, inorganics, metals, radionuclides, hexavalent chromium, and physical properties. Samples were taken from October 1992 through March 1993.

DOE - U.S. Department of Energy. 1994f. *Limited Field Investigation Report for the 100-KR-4 Operable Unit*. DOE/RL-93-79, U.S. Department of Energy, Richland, Washington.

This LFI was initiated to further characterize the groundwater contamination in the 100-KR area operable units: 100-KR-1, 100-KR-2, and 100-KR-3. In addition to the groundwater samples, other sampling data include surface water, sediment, soil, and aquatic biotic impacted by the KE and KW reactors. The media were sampled for VOCs, semivolatiles, inorganics, metals, pesticides, and radionuclides. Samples were collected in October 1991, September 1992, December 1992, March 1993, and June 1993.

2.6 Discrete Radioactive Particles and Other Direct Exposure Sources

In addition to the routine environmental monitoring documented in the Hanford Site annual reports, occasional special studies are performed to evaluate particular conditions. Key studies are described here.

Cooper, A. T., and R. K. Woodruff. 1993. *Investigation of Exposure Rates and Radionuclide and Trace Metal Distributions Along the Hanford Reach of the Columbia River*. PNL-8789, Pacific Northwest Laboratory, Richland, Washington.

This report documents the first major field study to investigate exposure rates along the Columbia River shoreline since the Sula (1980) investigation of 1979. Radionuclides and trace metals were surveyed between Priest Rapids Dam and north Richland. A smaller number of discrete radioactive particles were also noted.

EG&G Energy Measurements. 1990. *An Aerial Radiological Survey of the Hanford Site and Surrounding Area, Richland, Washington*. EGG-10617-1062, EG&G Energy Measurements, The Remote Sensing Laboratory, Las Vegas, Nevada.

EG&G used a radiation detection system in a helicopter to conduct a radiological survey of the Hanford area. The detection system was calibrated to suppress natural background radiation and therefore only detected sources of anthropomorphic gamma-emitting radioactivity. The aerial data are presented as isopleths overlaid onto maps of the Hanford Site. The aerial survey is an aid in locating areas with elevated exposure rates but does not stringently define contaminated areas.

Sula, M. J. 1980. *Radiological Survey of Exposed Shorelines and Islands of the Columbia River Between Vernita and the Snake River Confluence*. PNL-3127, Pacific Northwest Laboratory, Richland, Washington.

This report describes a radiological survey performed to evaluate the magnitude and distribution of radioactive contamination on the exposed shorelines of the Columbia River. External exposure rate measurements were made at nearly 30,000 locations. In addition, discrete particles of radioactive material were discovered. Discrete metallic flakes containing cobalt-60 were found. The highest areal density of particles was found on an island near D-reactor, although the presence of particles was indicated as far downriver as the survey extended.

Wade, C. D., and M. A. Wendling. 1994. *100-D Island USRADS Radiological Surveys Preliminary Report Phase II*. BHI-00-134, Bechtel Hanford, Inc., Richland, Washington.

This report describes the results of radiological surveys made in April 1994, over the upstream third of the island adjacent to the 100-D reactor area. The survey used the Ultrasonic Ranging and Data System. A significant note is that, "with a few exceptions, every area which was determined to be gamma elevated was sampled and the sampling removed the entire contamination present. In these locations, extremely small 'hot particles' were removed from the silt layer beneath the river rock." Analyses of these particles showed them to contain almost entirely cobalt-60 activity, between 0.4 and 22 microcuries each. A total of 103 particles were recovered from an area of about 5 hectares (12.5 acres).

2.7 National Environmental Policy Act (NEPA) Documents

Quantifying the potential for future releases of contaminants to the Columbia River from surplus facilities or waste sites requires a significant investigation, one which is beyond the scope of this report. However, several major environmental impact statements (EIS) concerning Hanford facilities and waste management practices have been written. Each of these reports contains evaluations of potential future conditions based on current or projected Hanford Site status.

DOE - U.S. Department of Energy. 1987. *Final Environmental Impact Statement, Disposal of Hanford Defense High-Level, Transuranic, and Tank Wastes, Hanford Site, Richland, Washington.* DOE/EIS-0113, U.S. Department of Energy, Washington, D.C.

This EIS addressed the selection and implementation of final disposal actions for high-level, transuranic, and tank wastes at Hanford. Although a decision on the existing single-shell tanks was ultimately deferred, this EIS provides descriptions of the potential releases of radionuclides to the groundwater, and ultimately the Columbia River, for each of the major waste categories at Hanford.

DOE - U.S. Department of Energy. 1989. *Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington, Draft Environmental Impact Statement.* DOE/EIS-0119D, U.S. Department of Energy, Washington, D.C.

and

DOE - U.S. Department of Energy. 1992c. *Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington, (Final Environmental Impact Statement).* DOE/EIS-0119F, U.S. Department of Energy, Washington, D.C.

This EIS, together with its addendum which constitutes the final EIS, describes the potential future releases of radionuclides to groundwater, and ultimately the Columbia River, from decommissioning the eight original Hanford reactors (excluding N Reactor) and the associated fuel storage basins. The preferred alternative for disposal was selected to be one-piece removal of the reactors from the riverside and burial in the 200 Areas.

DOE - U.S. Department of Energy. 1990c. *Low-Level Burial Grounds Dangerous Waste Permit Application: Request for Exemption from Lined Trench Requirements for Submarine Reactor Compartments.* DOE/RL-88-20, Supplement 1, U.S. Department of Energy, Richland, Washington.

and

DOE - U.S. Department of Energy. 1992d. *Low-Level Burial Grounds Dangerous Waste Permit Application: Request for Exemption from Lined Trench Requirements and from Land Disposal Restrictions for Residual Liquid at 218-E-12B Burial Ground Trench 94.* DOE/RL-88-20, Supplement 1, Revision 1, U.S. Department of Energy, Richland, Washington.

These two reports discuss decommissioned, defueled naval submarine reactor compartments containing radioactivity caused by exposure of structural components to neutrons during normal operation of the submarines. After all the alternatives were evaluated in the U.S. Department of the Navy 1984 environmental impact statement (Navy 1984), land burial of the submarine reactor compartments was selected as the preferred disposal option. The reactor compartments currently are sent to Trench 94 of the Hanford 218-E-12B Burial Ground. In addition to radioactivity, the reactor compartments disposed contain lead and PCBs as hazardous constituents. Modeling results indicate that release of contaminants to the groundwater or surface water will not occur until after long periods of time and that even after reaching the groundwater, contaminants will not be in excess of current regulatory limits, such as drinking water standards.

DOE - U.S. Department of Energy. 1994g. *Hanford Remedial Action Draft Environmental Impact Statement*. DOE/DEIS-0222. U.S. Department of Energy, Washington, D.C.

This EIS provides estimates of long-term risk resulting from the current groundwater plumes existing beneath the Site, as well as projections of future risks from non-tank, non-operating-facility waste management units.

Navy - U.S. Department of the Navy. 1984. *Final Environmental Impact Statement on the Disposal of Decommissioned, Defueled Naval Submarine Reactor Plants*. U.S. Department of the Navy, Washington, D.C.

This EIS discusses various alternatives for disposal of the radioactive portions of decommissioned nuclear submarines, leading to the selection of the Hanford Site as the location for permanent disposal. Estimates are presented for potential future radiation doses resulting from these activities.

Rhoads, K., B. N. Bjornstad, R. E. Lewis, S. S. Teel, K. J. Cantrell, R. J. Serne, J. L. Smoot, C. T. Kincaid, and S. K. Wurstner. 1992. *Estimation of the Release and Migration of Lead Through Soils and Groundwater at the Hanford Site 218-E-12B Burial Ground*. PNL-8356 Vol. 1, Pacific Northwest Laboratory, Richland, Washington.

This report evaluates the potential for radioactive and nonradioactive lead to migrate from buried submarine reactor compartments to the Columbia River. The estimated time of arrival of the contaminant plume ranges from 60,000 years to 4 million years.

Rhoads, K., B. N. Bjornstad, R. E. Lewis, S. S. Teel, K. J. Cantrell, R. J. Serne, L. H. Sawyer, J. L. Smoot, J. E. Szecsody, M. S. Wigmosta, and S. K. Wurstner. 1994. *Estimation of the Release and Migration of Nickel Through Soils and Groundwater at the Hanford Site 218-E-12B Burial Ground*. PNL-9791, Pacific Northwest Laboratory, Richland, Washington.

This report evaluates the potential for radioactive and nonradioactive nickel to migrate from buried submarine reactor compartments to the Columbia River. The estimated time of arrival of the contaminant plume ranges from 60,000 years to 4 million years.

3.0 Composite List of Identified Radionuclides and Chemicals

A data matrix (see Appendix A) was developed using the information found in the documents listed in Section 2.0. All radionuclides and chemicals analyzed in surface water (the Columbia River, springs, and seeps), sediment, groundwater, and soil samples in the 100, 300, and 1100 Areas are included. The data matrix is a composite list of all detected and not detected (i.e., analyzed for but not detected), radionuclides and chemicals from the reviewed literature. Sampling data from 1980 through 1994 were considered.

3.1 Risk-Based Standards Database

The development of the data matrix began with all chemicals identified in the Risk-Based Standards Database (Fowler et al. 1993). The Risk-Based Standards Database is a list of hazardous and radioactive substances reportedly found as contaminants or that are stored at DOE facilities nationwide. There are a total of 326 radionuclide and chemical entries for the Hanford Site. The radionuclides and chemicals in the database are sorted by their presence in the following media: Columbia River water, groundwater, soil, air, tank waste, and sediment. A total of 120 organic compounds, 133 inorganics, and 73 radionuclides were identified. These data formed the early basis for the data matrix.

Duplicate entries were removed from the database. Three mixtures (diesel fuel, hydrocarbons, and kerosene) are included. The primary database references were consulted for the concentration detected for each media. However, it was not possible to confirm the presence of the organics from the primary references cited in the database. Additional sources were reviewed to obtain information on the organic constituents.

3.2 Environmental Sampling Data Reports

The chemical analytical and radioanalytical data collected and presented in published environmental sampling reports were compiled and are presented in the data matrix in Appendix A. These reports include LFI reports, qualitative risk assessments, RI/FS reports, RCRA groundwater monitoring, and special studies reports. The titles and summaries of these documents are contained in Section 2.0. The scope was limited to the 100, 300, and 1100 Areas because they are most likely to have current impact.

The names of all radionuclides and chemicals examined (including those reported as nondetected) were added to the data matrix (Appendix A). The reported maximum concentration or activity, by media, is noted along with the background value, its reference, and the operable unit or geographical area where the sampling occurred. A total of 568 and 560 analytes were reported to be tested for in groundwater/Columbia River and soil/sediment, respectively, in the reviewed literature.

Of the analytes tested, 73 were detected in groundwater or Columbia River water, and 92 were detected in soil and sediment. Many of the analytes found are naturally occurring in groundwater and soil or are present as a result of global radioactive fallout.

A separate data matrix in Appendix A was prepared for incorporation of data related to existing groundwater plumes in areas outside the area of primary interest (i.e., the 200 Areas and 600 Area groundwater plumes).

3.3 Detected Analytes

Table 3.1 lists the 73 radionuclides and chemicals detected and their maximum concentration or activity in groundwater and Columbia River water. These maximum values are used in the screening process described in Section 4.0. Table 3.2 lists the 92 radionuclides and chemicals detected and their maximum concentration or activity in sediment and soil. Table 3.3 lists the maximum concentration or activity reported in existing Hanford groundwater plumes away from the river.

The data on radionuclide activity in sediment were compared with values reported by the Washington State Department of Health (Wells 1994). All contaminants included in Wells (1994) were included in the tables.

Tables 3.1, 3.2, and 3.3 are used in the screening criteria described in Section 4.0.

Table 3.1. Maximum Detected Concentrations in the Columbia River and Groundwater in the Hanford Site 100, 300, and 1100 Areas Near the Columbia River, 1980-1994

		Concentration in	
	Name of Analyte	Surface Water	Groundwater
1	ACETONE	11 µg/L (a)	30 µg/L
2	ALUMINUM		4,810 µg/L
3	AMERICIUM 241		0.021 pCi/L (b)
4	AMMONIA		70 µg/L
5	AMMONIUM		1,630 µg/L
6	ANTIMONY		60 µg/L
7	ANTIMONY 125		20 pCi/L
8	ARSENIC	3.4 µg/L	17 µg/L
9	BARIUM	48.2 µg/L	719 µg/L
10	BERYLLIUM		6 µg/L
11	BERYLLIUM 7 (c)		
12	BIS(2-ETHYLHEXYL) PHTHALATE		50 µg/L
13	BISMUTH (c)		
14	BORON (c)		
15	CADMIUM		31 µg/L
16	CALCIUM	35,900 µg/L	302,000 µg/L
17	CARBON 14		23,000 pCi/L
18	CESIUM 134	0.012 pCi/L	
19	CESIUM 137	0.13 pCi/L	0.5 pCi/L
20	CHLORIDE	870 µg/L	122,000 µg/L
21	CHLOROFORM		42 µg/L
22	CHROMIUM	22 µg/L	1,950 µg/L
23	COBALT		8 µg/L
24	COBALT 60	0.011 pCi/L	140 pCi/L
25	COPPER	22 µg/L	516 µg/L
26	CYANIDE		21.1 µg/L
27	DICHLOROETHYLENE, 1,2-		200 µg/L
28	DICHLOROETHYLENE, 1,2-trans-		130 µg/L
29	EUROPIUM 154		2 pCi/L
30	FLUORIDE	150 µg/L	2,080 µg/L
31	HYDRAZINE		7 µg/L
32	IODINE 129	0.16 pCi/L	
33	IRON	463 pCi/L	37,300 µg/L
34	LEAD		173 µg/L
35	LITHIUM (c)		
36	MAGNESIUM	9,860 µg/L	55,000 µg/L
37	MANGANESE	22.8 µg/L	400 µg/L
38	MERCURY		8.9 µg/L
39	METHYL ETHYL KETONE		18 µg/L
40	METHYLENE CHLORIDE		3,040 µg/L

Table 3.1. (contd)

		Concentration in	
	Name of Analyte	Surface Water	Groundwater
41	NICKEL	31 μg/L	479 μg/L
42	NITRATE	480 μg/L	90,000 μg/L
43	NITRITE		60,000 μg/L
44	PHOSPHATE		3,240 μg/L
45	PLUTONIUM 238		0.01 pCi/L
46	PLUTONIUM 239		0.03 pCi/L
47	POTASSIUM	2,430 μg/L	11,300 μg/L
48	RADIUM 226		0.3 pCi/L
49	RUTHENIUM 106+D		34.4 pCi/L
50	SELENIUM		17.2 μg/L
51	SILICON (c)		
52	SILVER		19 μg/L
53	SODIUM	13,800 μg/L	200,000 μg/L
54	STRONTIUM		310 μg/L
55	STRONTIUM 90	28 pCi/L	80,000 pCi/L
56	SULFATE	8,600 μg/L	600,000 μg/L
57	SULFIDE		3,000 μg/L
58	TECHNETIUM 99		2,270 pCi/L
59	TETRACHLOROETHYLENE		39 μg/L
60	THALLIUM		4 μg/L
61	THORIUM 228		3 pCi/L
62	THORIUM 232		44.5 pCi/L
63	TITANIUM (c)		
64	TOLUENE	4.7 μg/L	2.9 μg/L
65	TRICHLOROETHYLENE		24.1 μg/L
66	TRITIUM (HYDROGEN 3)	4,430 pCi/L	1,900,000 pCi/L
67	URANIUM 233		3.3 pCi/L
68	URANIUM 234	18 pCi/L	120 pCi/L
69	URANIUM 235	0.01 pCi/L	17 pCi/L
70	URANIUM 238	19 pCi/L	93 pCi/L
71	VANADIUM		40 μg/L
72	XYLENE	4 μg/L	
73	ZINC	11 μg/L	8,800 μg/L
(a)	μg/L = micrograms per liter.		
(b)	pCi/L = picocuries per liter.		
(c)	Concentrations of these chemicals fall within		
	their respectively occurring background levels.		

Table 3.2. Maximum Detected Concentrations in Soil and Sediment in the Hanford Site 100, 300, and 1100 Areas, 1980-1994

		Concentration in	
	Name of Analyte	Soil	Sediment
	Radionuclides		
1	AMERICIUM 241	34 pCi/g (a)	
2	ANTIMONY 124		1.2 pCi/g
3	CARBON 14	34 pCi/g	
4	CESIUM 134	0.04 pCi/g	0.29 pCi/g
5	CESIUM 137	2,900 pCi/g	6 pCi/g
6	COBALT 60	18,000 pCi/g	4.9 pCi/g
7	EUROPIUM 152	59,000 pCi/g	2.41 pCi/g
8	EUROPIUM 154	20,000 pCi/g	0.24 pCi/g
9	EUROPIUM 155	6,200 pCi/g	0.32 pCi/g
10	NEPTUNIUM 237		0.606 pCi/g
11	NICKEL 63	20,000 pCi/g	
12	PLUTONIUM 238	11 pCi/g	0.00115 pCi/g
13	PLUTONIUM 239	230 pCi/g	0.071 pCi/g
14	PLUTONIUM 240	(w/Pu239) (b)	
15	POTASSIUM 40	16 pCi/g	23 pCi/g
16	RADIUM 226	3.09 pCi/g	1.7 pCi/g
17	STRONTIUM 90	950 pCi/g	207 pCi/g
18	TECHNETIUM 99	0.67 pCi/g	0.5 pCi/g
19	THORIUM 228	1.61 pCi/g	3 pCi/g
20	THORIUM 232	1.1 pCi/g	3.2 pCi/g
21	THORIUM 234	ND (c)	0.812 pCi/g
22	TRITIUM (HYDROGEN 3)	1,600 pCi/g	
23	URANIUM 233	3.9 pCi/g	2.3 pCi/g
24	URANIUM 234		3.9 pCi/g
25	URANIUM 235	1.23 pCi/g	0.1 pCi/g
26	URANIUM 238	4.7 pCi/g	3.2 pCi/g
27	ZINC 65	ND	0.24 pCi/g
28	ZIRCONIUM 95	0.56 pCi/g	
	Chemicals		
29	ACENAPHTHENE	210 μg/kg (d)	
30	ALUMINUM	26,700,000 μg/kg	9,350,000 μg/kg
31	AMMONIA	12,800 μg/kg	12,000 μg/kg
32	ANTHRACENE	430 μg/kg	
33	AROCLOR 1248 (PCB)	9,900 μg/kg	
34	ARSENIC	47,000 μg/kg	7,500 μg/kg
35	BARIUM	672,000 μg/kg	120,000 μg/kg
36	BENZENE	4,500 μg/kg	
37	BENZO(G,H,I)PERYLENE	410 μg/kg	
38	BENZO[a]ANTHRACENE	940 μg/kg	
39	BENZO[a]PYRENE	810 μg/kg	
40	BENZO[b]FLUORANTHENE	890 μg/kg	
41	BENZO[K]FLUORANTHENE	760 μg/kg	
42	BENZOIC ACID	1,700 μg/kg	
43	BERYLLIUM	8,000 μg/kg	1,100 μg/kg
44	BIS(2-ETHYLHEXYL) PHTHALATE	68,000 μg/kg	
45	CADMIUM	1,800 μg/kg	2,700 μg/kg
46	CALCIUM	40,800,000 μg/kg	4,460,000 μg/kg
47	CHLORDANE	4,500 μg/kg	
48	CHLORIDE	1,100 μg/kg	

Table 3.2. (contd)

		Concentration in	
	Name of Analyte	Soil	Sediment
49	CHLORINE (e)		
50	CHROMIUM	259,000 μg/kg	12,200 μg/kg
51	CHRYSENE	920 μg/kg	
52	COBALT	34,100 μg/kg	11,500 μg/kg
53	COPPER	140,000,000 μg/kg	40,000 μg/kg
54	CYANIDE	1,050 μg/kg	
55	DIBENZOFURAN	130 μg/kg	
56	DIESEL FUEL	2,800,000 μg/kg	
57	ENDRIN ALDEHYDE	3.3 μg/kg	
58	ETHYL BENZENE	32,000 μg/kg	
59	FLUORANTHENE	1,800μg/kg	
60	FLUORENE	190 μg/kg	
61	FLUORIDE	4,700 μg/kg	
62	FLUORINE (e)		
63	INDENO(1,2,3-CD)PYRENE	520 μg/kg	
64	IRON	33,500,000 μg/kg	71,000,000 μg/kg
65	KEROSENE	3,085,000 μg/kg	
66	LEAD	540,000 μg/kg	73,000 μg/kg
67	LITHIUM (e)		
68	MAGNESIUM	11,600,000 μg/kg	7,600,000 μg/kg
69	MANGANESE	839,000 μg/kg	578,000 μg/kg
70	MERCURY	4,300 μg/kg	
71	METHYL-2-PENTANONE, 4-	22,000 μg/kg	
72	METHYLENE CHLORIDE	120 μg/kg	
73	METHYLNAPHTHALENE, 2-	42 μg/kg	
74	NICKEL	221,000 μg/kg	19,700 μg/kg
75	NITRATE	30,400 μg/kg	
76	PHENANTHRENE	1,500 μg/kg	
77	POTASSIUM	4,980,000 μg/kg	1,900,000 μg/kg
78	PYRENE	1,200 μg/kg	
79	SELENIUM	4,200 μg/kg	
80	SILVER	1,900 μg/kg	2,500 μg/kg
81	SILVER CHLORIDE	17,300,000 μg/kg	
82	SODIUM	1,770,000 μg/kg	920,000 μg/kg
83	STRONTIUM	67,000 μg/kg	
84	STRONTIUM CHLORIDE	1 μg/kg	
85	SULFATE (SULFUR)	131,000 μg/kg	
86	TITANIUM (e)		
87	TOLUENE	350,000 μg/kg	
88	TOTAL PETROLEUM HYDROCARBON	1.26E+08	
89	VANADIUM	389,000 μg/kg	82,200 μg/kg
90	XYLENE	1,800,000 μg/kg	
91	ZINC	309,000 μg/kg	397,000 μg/kg
92	ZIRCONIUM (e)		
(a)	pCi/g = picocuries per gram.		
(b)	w/Pu239 = concentration included in that reported for plutonium-239.		
(c)	ND = not detected.		
(d)	μg/kg = micrograms per kilogram.		
(e)	Concentrations of these chemicals fall within		
	their respectively occurring background levels.		

Table 3.3. Maximum Detected Concentrations in Groundwater in the Hanford Site 100, 200, and 600 Areas Away from the Columbia River, 1980-1994

Name of Analyte	Number of Plumes	Concentration
100 Areas		
Chromium (+6)	3	1,570 ppb
Nitrate	10	130,000 ppb
Strontium-90	8	1,800 pCi/L
Tritium (Hydrogen-3)	4	80,000 pCi/L
200 West Area		
Arsenic	4	24 ppb
Carbon Tetrachloride	1	6,559 ppb
Chloroform	2	1,595 ppb
Chromium	5	323 ppb
Fluoride	3	10,067 ppb
Iodine-129	2	30 pCi/L
Nitrate	5	1,322,000 ppb
Technetium-99	5	26,602 pCi/L
Trichloroethylene	3	32 ppb
Tritium (Hydrogen-3)	3	6,193,000 pCi/L
Uranium	4	1,616 pCi/L
200 East Area		
Arsenic	4	24ppb
Cesium-137	1	1,326 pCi/L
Chloroform	1	7 ppb
Chromium	4	288 ppb
Cobalt-60	2	440 pCi/L
Cyanide	2	893 ppb
Iodine-129	3	20 pCi/L
Nitrate	7	397,000 ppb
Plutonium-239/240	1	69 pCi/L
Strontium-90	5	5,149 pCi/L
Technetium-99	2	22,163 pCi/L
Tritium (Hydrogen-3)	5	4,126,000 pCi/L
Uranium	1	27 pCi/L
600 Area (Solid Waste Landfill Site)		
Chloroform	1	0.5 ppb
Dichloroethane, 1, 1-	1	7 ppb
Tetrachloroethene	1	12 ppb
Trichloroethane, 1, 1, 1-	1	50 ppb
Trichloroethene	1	7 ppb
(a) pCi/L = picocuries per liter.		
(b) ppb = parts per billion.		

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4.0 Screening Approach

The review of the available data indicated that concentrations of various radionuclides, carcinogenic chemicals, and hazardous chemicals had been measured in Columbia River water (Columbia River, springs, and seeps), groundwater, river sediment, and near-river soil. A multi-stage screening process to prioritize these various contaminants in terms of human health risk and ecosystem risk was developed. Each stage of the process identifies contaminants of interest. The combined results of the entire screening process then compose the total list of contaminants of concern.

The conceptual model for human health risk is associated with a scenario of a dedicated river user. The reference screening exposure scenario involves a person who frequents the shores of the river, drinks 2 liters/day of untreated river water, consumes about 0.25 kilograms/day (100 kilograms/year) (CRITFC 1994) of freshwater fish, and has an incidental sediment ingestion rate of 10 milligrams/day (almost 4 grams/year). This conceptual model is an adaptation and expansion of the Hanford Site risk assessment methodology (DOE 1992e).

The conceptual models for ecosystem risk are simpler, relying on the EPA Ambient Water Quality Criteria (EPA 1992) and on a fraction of the concentrations that result in mortality for fish.

All analytes found in the reviewed literature, which related to the 100, 300, and 1100 Areas, regions along the banks of the Columbia River, or inland contaminant plumes, were compiled (see Appendix A). Initial screening eliminated the contaminants on the list that showed no detectable levels of activity or concentration. In addition, analytes which were present only in tank wastes and not in environmental media were eliminated from the study.

4.1 Screening Equations

The screening process operates on one portion of the available data at a time. Separate screenings are used for measurements in Columbia River water, groundwater, river sediment, and near-river soil. Within each of these divisions, further subdivisions address radionuclides, carcinogens, human toxins, and fish toxins. All of the screenings rely on river water concentration or a surrogate as a starting point. Procedures for estimating the surrogates are described below.

4.1.1 Radionuclide Screening

The screening is based on a scenario of exposure to a dedicated river user (see definition above). Internal risks are estimated using the EPA slope factor for ingestion (EPA 1994a). The EPA slope factor represents the lifetime excess total cancer risk per unit of intake. External exposure to contaminated sediment is addressed by assuming the parameters associated with the EPA slope factor for external exposure are appropriate (EPA 1994a).

A relationship between the concentration of the contaminant in the water and the concentration in the sediment is required. For the screening, this relationship is assumed to be described by a ratio of 1:100,000 (i.e., the concentration of the contaminant in the sediment is assumed to be 100,000 times higher than in the Columbia River waters). This assumption is based on review of the very limited number of samples for which both river water and sediment values were available, as well as on an empirical equation developed for radionuclides in the Columbia River incorporated in the GENII computer code (Napier et al. 1988, p. 4.82).

The screening equation for radionuclides is:

$$SCREEN = C_w \left[\frac{100{,}000 * SS}{1000} + (730 + 100 * BCF + 100{,}000 * 0.0036) * IS\right] \quad (1)$$

where C_w = measured or surrogate water concentration, pCi/L
100,000 = sediment/water ratio, L/kg
SS = radionuclide slope factor for external exposure, risk/year per pCi/g
1000 = unit conversion, g/kg
730 = water consumption of 2 L/day for 1 year
100 = fish consumption of 100 kg/year
BCF = bioconcentration factor for fish, L/kg
0.0036 = sediment consumption of 10 mg/day, giving 3.6 g/year
IS = radionuclide slope factor for ingestion, risk/pCi.

Values resulting from this screening which approach or are greater than 10^{-6} imply radionuclides of potential concern.

4.1.2 Carcinogenic Chemical Screening

The conceptual exposure patterns for carcinogens in river water are the same as those for radionuclides; however, there is no factor for external exposure. Because the chemical cancer potency factors for oral exposure are in units of inverse milligram per kilogram per day, the consumption terms are put in daily, rather than annual, units (EPA 1994a).

$$SCREEN = C_w \left[2 + 0.27 * BCF + 100{,}000 * 1 \times 10^{-5}\right] (0.001) \frac{CPF}{70} \quad (2)$$

where C_w = measured or surrogate water concentration, μg/L
2 = water consumption of 2 L/day
0.27 = consumption of 100 kg/year of fish, on a daily basis 0.27 kg
BCF = bioconcentration factor for fish, L/kg
100,000 = sediment/water ratio, L/kg
1×10^{-5} = consumption of 10 mg/day of sediment, kg
0.001 = conversion factor, micrograms to milligrams
CPF = cancer potency factor, $(mg/kg/day)^{-1}$
70 = assumed weight of an adult, 70 kg.

Values resulting from this screening which approach or are greater than 10^{-6} imply chemicals of potential concern.

4.1.3 Toxic Chemical Screening

For hazardous, but noncarcinogenic, chemicals, the ranking is based on a ratio of the estimated daily intake to the EPA chronic oral reference dose (EPA 1994a). The conceptual scenario is the same as for the radionuclides or carcinogens.

$$\text{SCREEN} = C_w \, [2 + 0.27 * \text{BCF} + 100{,}000 * 1 \times 10^{-5}] \, \frac{(0.001)}{70 * \text{RfD}} \tag{3}$$

where C_w = measured or surrogate water concentration, μg/L
2 = water consumption of 2 L/day
0.27 = consumption of 100 kg/year of fish, on a daily basis 0.27 kg
BCF = bioconcentration factor for fish, L/kg
100,000 = sediment/water ratio, L/kg
1×10^{-5} = consumption of 10 mg/day of sediment, kg
0.001 = conversion factor, micrograms to milligrams
70 = assumed weight of an adult, 70 kg
RfD = EPA chronic oral reference dose, mg/kg/day.

Values resulting from this screening which approach or are greater than unity imply chemicals of potential concern.

4.1.4 Ambient Water Quality Criteria Screening

For aquatic biota, the measured or surrogate concentration of the contaminant in water is compared with the applicable EPA water quality criterion (EPA 1992). The ambient water quality criteria are values of the concentrations of chemicals in water that are considered by the EPA to be protective of aquatic life. The screening equation is

$$\text{SCREEN} = \frac{C_w}{\text{AWQC}} \tag{4}$$

where C_w = measured or surrogate water concentration, pCi/L
AWQC = ambient water quality criterion, μg/L.

Values resulting from this screening which approach or are greater than unity imply chemicals of potential concern.

4.1.5 Aquatic Biota Toxicity Screening

Limited data were available that identify the concentrations of certain chemicals that result in toxic effects to aquatic life. Where possible, the threshold concentration for fresh water at which any effect was noted was used. Although it would have been preferable to use information that related directly to the initiation of distress in aquatic life, rather than mortality, such information (e.g., the threshold limit value for the medium) was available for only a few chemicals. Therefore, the lowest concentration lethal to 50 percent of small, freshwater fish (e.g., guppies, mosquito fish, rainbow trout) tested was also used (EPA 1985). To relate these lethal effects to less significant effects, the screening used a value of 1 percent of the LC50 in the determination. For a few analytes for which fish data were not available, test results for crayfish or insects were used as a surrogate. The equation is

$$\text{SCREEN} = \frac{C_w}{(\text{LD50} \ / \ 100)} \quad \text{else} \quad \frac{C_w}{\text{TLM}} \tag{5}$$

where C_w = measured or surrogate water concentration, pCi/L
LD50 = concentration of contaminant lethal to 50 percent of the tested fish population in time periods ranging from 48 to 96 hours (LC_{50}), μg/L
TLM = threshold limit for fresh water (TLM), μg/L.

Values using this screening approach or values greater than unity imply chemicals of potential concern.

A concern has been raised that groundwater, filtering through gravel beds into the waters of the Columbia River, could directly impact fish eggs laid in the gravels without prior dilution by Columbia River water. Sources of data related to the impact of the listed contaminants on fish eggs were sought. Very few positive connections between research on fish egg survival and contaminant concentrations were found, making it impossible to screen directly on this concept.

4.2 Estimation of Contaminant Concentrations in River Water

All of the screening equations presented in the preceding section require an estimate of the contaminant's maximum measured concentration in river water. Only the direct river measurements provide this information. For the other media, an estimated, surrogate water concentration must be developed. Radionuclide concentrations compiled were generally given in units of picocuries/liter or picocuries/gram. Chemical concentrations were standardized to units of micrograms/liter or micrograms/kilogram. Therefore, separate conversions were developed for radionuclides and chemicals.

4.2.1 Radionuclides

Separate sets of assumptions were needed to prepare screening surrogates for concentrations in river water for measurements in groundwater, river sediment, and near-river soil.

4.2.1.1 Groundwater

Groundwater adjacent to the Columbia River can flow into the river, and Columbia River water can flow into the groundwater, depending on river flow. Therefore, concentrations of contaminants in groundwater near the river are difficult to predict, and concentrations measured near the shore differ from those measured further inland. Flow rates from groundwater to the Columbia vary from location to location; individual springs may have very low flow rates. An average groundwater discharge to the Columbia River of 3 cubic feet per second (cfs) was modeled by Kipp et al. (1976) for a 8.3-kilometer

(5-mile) length of the river near the Hanford townsite. Raymond et al. (1976) and Cline et al. (1985) report an estimated discharge of 100 cfs over the entire Hanford Reach. More recent research (Wuestner and Devary 1993) indicates that 100 cfs is an upper bound. For conservatism (i.e., to provide an overestimate of the resulting concentration in the river), this upper value of 100 cfs was adopted for the screening. In effect, this implies that the entire volume of groundwater that flows from beneath Hanford to the Columbia River is contaminated to the maximum level reported. Thus, the conversion used is

$$C^{o}_{w} = C_{gw} * \frac{100}{100{,}000} \qquad (6)$$

where C^{o}_{w} = surrogate river water concentration used in the screening, pCi/L
C_{gw} = measured groundwater concentration, pCi/L
100 = groundwater discharge rate, cfs
100,000 = approximate annual average flow rate of the Columbia River at Hanford, cfs.

4.2.1.2 River Sediment

Sediment within the river is both a reservoir of contaminants and a source of contamination of the river water, as the material desorbs or resuspends into the water column. Accurate representation of this process requires detailed knowledge of the chemical interactions of the contaminant and the water. Information at this level of detail is not available for most of the contaminants considered. For consistency with the dose estimation assumptions, this relationship is assumed to be described by an equilibrium ratio of 1:100,000 (i.e., the concentration of the contaminant in the sediment is assumed to be 100,000 times higher than in the Columbia River water). The conversion used is then

$$C^{o}_{w} = \frac{C_{sed} * 1000}{100{,}000} \qquad (7)$$

where C^{o}_{w} = surrogate river water concentration used in the screening, pCi/L
C_{sed} = sediment concentration, pCi/g
1000 = unit conversion, g/kg
100,000 = assumed concentration ratio, L/kg.

4.2.1.3 Near-River Soil

Contaminants in waste sites or other sites adjacent to the Columbia River may not pose a current hazard to down-river users of the river, but they may pose a threat of future contamination of the river. The possibility also exists that such sources may be contributing as-yet undetected contamination to the river. One of the goals of the Columbia River Comprehensive Impact Assessment is to tie Hanford cleanup activities to the potential for river contamination. In this spirit, contaminated soil near the river is included as a possible source of contaminants. Adequate consideration of these contaminants must include site-specific details about how they could be transported from their current locations into the groundwater and hence into the Columbia River. For the purpose of screening, all contaminants are assumed to be environmentally mobile and potentially soluble in groundwater (contrast this assumption to that used for contaminants in sediment, where they are assumed to be tightly bound).

Based on this assumption, the surrogate groundwater contamination is assumed to have the same concentration of contaminants as the soil. The total area of industrial activity comprises approximately 6 percent of the Hanford Site (Dirkes et al. 1994, p. 5). Because it is unreasonable to assume that all of Hanford soil is contaminated to the maximum concentration reported, an effective area of 1 percent is assumed. The set of assumptions used to convert groundwater to river water concentrations is then also applied. The resulting equation for surrogate river water concentration resulting from soil is

$$C^o_w = C_{soil} * \frac{(1000 * 1 * 100 * 0.01)}{100{,}000} \tag{8}$$

where C^o_w = surrogate river water concentration used in the screening, pCi/L
C_{soil} = concentration in soil, pCi/g
1000 = unit conversion, g/kg
1 = assumption of soil/groundwater concentration equivalency, kg/L
100 = groundwater discharge rate, cfs
0.01 = fraction of total area contaminated, dimensionless
100,000 = approximate annual average flow rate of the Columbia River at Hanford, cfs.

4.2.2 Chemicals

Conversions from measured values to surrogate river water concentrations are also required for carcinogenic and hazardous chemical contaminants. The assumptions are the same as for radionuclides; however, the measured units are generally in micrograms/kg, rather than pCi/g, and some conversions differ by factors of 1000.

4.2.2.1 Groundwater

The conversion is numerically identical to that for radionuclides:

$$C^o_w = C_{gw} * \frac{100}{100{,}000} \tag{9}$$

where C^o_w = surrogate river water concentration used in the screening, μg/L
C_{gw} = measured groundwater concentration, μg/L
100 = groundwater discharge rate, cfs
100,000 = approximate annual average flow rate of the Columbia River at Hanford, cfs.

4.2.2.2 River Sediment

The conversion is similar to that for radionuclides with the g/kg conversion removed:

$$C^o_w = \frac{C_{sed}}{100{,}000} \tag{10}$$

where C^o_w = surrogate river water concentration used in the screening, μg/L
C_{sed} = sediment concentration, μg/kg
100,000 = assumed concentration ratio, L/kg.

4.2.2.3 Near-River Soil

The conversion is similar to that for radionuclides with the g/kg conversion removed:

$$C^o_w = C_{soil} * \frac{(1 * 100 * 0.01)}{100,000} \quad (11)$$

where C^o_w = surrogate river water concentration used in the screening, μg/L
C_{soil} = concentration in soil, pCi/g
1 = assumption of soil/groundwater concentration equivalency, kg/L
100 = groundwater discharge rate, cfs
0.01 = fraction of total area contaminated, dimensionless
100,000 = approximate annual average flow rate of the Columbia River at Hanford, cfs.

4.3 Screening Results

Application of the equations and assumptions defined above results in a series of complementary, but not necessarily intercomparable, screening values for each contaminant. The varying numbers of assumptions and associated varying degrees of conservatism require that each of the screenings be evaluated separately. The results of the combined screenings, however, then define the overall list of contaminants of interest. The complete list of radionuclides and chemicals entered into the project database is presented in Appendix A. The parameters used in the calculation are presented in Appendix B. The complete numerical results are presented in Appendix C. The overall results and interpretation of the screening are given here.

During the screening process, a few radionuclides and chemicals were identified as of potential interest, but not carried forward. Some items were measurements determined to be within the naturally occurring background levels of these materials. These materials included the radionuclides beryllium-7 and potassium-40 and the chemicals barium, bismuth, boron, chlorine, fluorine, lithium, silicon, silver, sulfide, titanium, vanadium, and zirconium. In addition, several materials were identified by the screening process that the EPA (EPA 1991; EPA 1989) considers nonhazardous under environmental conditions. These materials removed from further consideration included aluminum, calcium, iron, magnesium, potassium, and sodium.

4.3.1 River Water Sample Screening

Of the thousands of available environmental samples, relatively few show positive identification of contaminants directly in the waters of the Columbia River. A screening level was used to account for over 1) 95 percent of the carcinogenic risk for each result, above a cutoff of 10^{-6}, or 2) a non-carcinogenic hazard ranking of greater than 0.1. The individual screenings and the contaminants identified via each are listed in Table 4.1.

Table 4.1. Contaminants of Potential Interest Identified via Screening of Columbia River Samples

Radionuclide Screening	Carcinogenic Chemical Screening	Hazard Index Screening	Ambient Water Quality Criteria Screening	Aquatic Toxicant Screening
Cesium-134	Arsenic	Arsenic	Copper[(a)]	Arsenic
Cesium-137		Copper[(a)]	Nickel[(a)]	Copper[(a)]
Cobalt-60		Manganese	Zinc	Nickel[(a)]
		Nickel[(a)]		Nitrate
		Nitrate		Xylene[(b)]
		Toluene[(b)]		Zinc
		Xylene[(b)]		
		Zinc		

(a) See discussion in Section 4.4 on samples near limit of detection.
(b) See discussion in Section 4.4 on suspect samples.

The two isotopes of radiocesium, cesium-134 and cesium-137, are present in worldwide fallout. It is likely that these two contaminants are largely derived from non-Hanford sources. The Hanford Environmental Dose Reconstruction Project did not identify these two radionuclides as resulting from significant Hanford releases (Napier 1993).

Several contaminants are highlighted in Table 4.1 with footnotes. These indicate a potential problem with the screening result on the basis of source information. These difficulties are described in Section 4.4.

4.3.2 Groundwater Sample Screening

A very large fraction of available Hanford-related environmental samples are of groundwater. Only those taken within about a kilometer of the river were used in compiling the database used for the screening. Even so, many positive samples were noted. Most of the samples were derived from investigations of the Hanford operating areas (100, 300), but many were from wells located near the river but far from the reactor, fuel fabrication, and research sites. Contaminants identified for investigation include several metals. The individual screenings and the contaminants identified via each are listed in Table 4.2.

4.3.3 River Sediment Sample Screening

Because the Hanford Reach is a relatively fast-flowing portion of the river, there is actually little accumulation of sediment at Hanford. Accordingly, sediment samples represent a very small portion of the historical Hanford data. This is a clear area for future sampling work. Nevertheless, the sediment samples did provide sufficient information to apply the screening technique. The individual screenings and the contaminants identified via each are listed in Table 4.3. Like the river water screening, this process identified two isotopes of cesium, both of which are most likely associated with global fallout.

Table 4.2. Contaminants of Potential Interest Identified via Screening of Groundwater Near the Columbia River

Radionuclide Screening	Carcinogenic Chemical Screening	Hazard Index Screening	Ambient Water Quality Criteria Screening	Aquatic Toxicant Screening
Cobalt-60	Chromium	Antimony	Chromium	Chromium
Strontium-90		Copper	Mercury	Copper
		Mercury		Nitrate/Nitrite
		Nitrate/Nitrite		Zinc
		Phosphate		

Table 4.3. Contaminants of Potential Interest Identified via Screening of Columbia River Sediment Samples

Radionuclide Screening	Carcinogenic Chemical Screening	Hazard Index Screening	Ambient Water Quality Criteria Screening	Aquatic Toxicant Screening
Cesium-134	Chromium	Arsenic	Chromium	Chromium
Cesium-137		Copper	Lead	Zinc
Cobalt-60		Lead		
Europium-152		Zinc		

4.3.4 Near-River Soil Sample Screening

Contaminants measured in soil near the Columbia River are generally not an immediate hazard because they are currently in the soil and not subject to mass transport to the river, and subsequent human and biotic exposure. However, their existence is the primary reason for continuing cleanup of the Hanford operating areas, and it is useful to have a screening prioritization. It is also useful to direct future sampling efforts to determine if any of the contaminants most likely to cause problems are beginning to reach the river. Because of the nature of the contamination (generally solids in or associated with soil) and the nature of the activities carried out at Hanford over its history, these contaminants differ somewhat from those actually found in more mobile media (river water, groundwater, and sediment). Even so, it is informative to note the similarities in the list generated via the soil screening with those lists generated for the other media. The individual screenings and the contaminants identified via each are listed in Table 4.4.

Table 4.4. Contaminants of Potential Interest Identified via Screening of Soil Near the Columbia River

Radionuclide Screening	Carcinogenic Chemical Screening	Hazard Index Screening	Ambient Water Quality Criteria Screening	Aquatic Toxicant Screening
Cesium-137	Arochlor 1248 (PCB)	Arsenic	Arochlor 1248 (PCB)	Chlordane
Cobalt-60	Benzo(a)pyrene[a]	Chlordane	Chlordane	Mercury
Europium-152	Chromium	Copper	Chromium	Zinc
Europium-154	Indeno(1,2,3-CD) pyrene[a]	Lead	Copper	Diesel Fuel
		Mercury	Lead	
		Nitrate	Mercury	
		Silver Chloride		
		Zinc		
		Diesel Fuel		

(a) See discussion in Section 4.4.

4.4 Use of Suspect Measurements

The majority of the measurements taken over the past 15 years were collected in accordance with modern quality assurance procedures (Dirkes et al. 1994). The data from the references used in this report are traceable and of high quality. All data recorded in the referenced studies were used in the development of the screening approach reported here.

During the evaluation of tens of thousands of media samples for hundreds of analytes over a period of many years, it is statistically expected that an occasional analysis will result in incorrect identification of an analyte or its quantity. The quality assurance procedures in place on the major Hanford Site databases generally serve to identify these abnormal values. For scientific completeness, the reported values are generally included in the databases with an indicator that they are potentially spurious. In the course of the evaluations for this report, six potential constituents of concern with single, questionable, measured results were encountered with the potential to influence the selection criteria, two in soil and four in Columbia River water.

Two of the chemicals labeled with a footnote in Table 4.1 are toluene and xylene. These two chemicals were identified as coming from a single sample which may have been contaminated during sampling or analysis because these and other chemicals identified in that one sample are common laboratory and industrial solvents (Dirkes et al. 1993, p. 4.1). Since the suspect sample was paired with another suspect sample from upstream of Hanford, which also indicated high concentrations of organic contaminants, it is unlikely that these compounds are elevated in river water as a result of releases from Hanford.

Two other chemicals labeled with a footnote in Table 4.1 are copper and nickel. These two chemicals and several more identified in Table C.1 (see SW-LD notations) were very near the lower limits of detection in a series of samples at the Richland pumphouse (Dirkes et al. 1993). This reference compared concentrations of 20 volatile organic chemicals, 19 metals, and 7 anions upstream from Hanford (Vernita Bridge) and downstream (Richland). No volatile organic chemicals were routinely detected at either location. The concentrations of most metals were also very low. However, copper and nickel were each reported one time (out of nine sampling periods) as being slightly above the limit of detection. The limit of detection for copper for this study was 20 micrograms/liter. The single reported positive sample was 22 micrograms/liter. The limit of detection for nickel was 30 micrograms/liter. The single reported positive sample was 31 micrograms/liter. These values probably do not represent the actual level of river contamination.

Two chemicals labeled with a footnote in Table 4.4 are benzo(a)pyrene and indeno(1,2,3-CD) pyrene. Both of these chemicals appear only once in the database of samples, and both are analytes from the same physical sample. This one sample is noted in the historical record as being "suspect" because the analysis results for all contaminants evaluated were very high and not repeated in other nearby samples. It is likely that these two chemicals do not need to be on the master list for further evaluation.

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5.0 Discrete Radioactive Particles

The presence of small, discrete particles of radioactive material was discovered by Sula during a shoreline survey in 1978-1979 (Sula 1980). In the 1978-1979 survey, Sula reported finding 188 discrete particles of contaminated material. The majority of the discrete particles were found buried in rocky, flat areas with little or no vegetation. Sula recovered 14 particles for special study. Laboratory analysis identified the gamma radiations emitted from the particles to be entirely due to cobalt-60, with activities ranging from 1.7 to 24 microcuries. Sula (1980, p. 36) describes the particles as

> When isolated, the particles were barely visible to the naked eye, appearing as small, dark colored chips or flakes of roughly equal size. Microscopic examination of three particles showed them to be metallic appearing flakes with diameters of approximately 0.1 mm. The particles were found to vary in elemental composition, but all contained significant proportions of chromium, iron, and cobalt characteristic of the alloy stellite, used in valve and pump components in all of the production reactors.

Sula declined to predict how many particles exist in the Columbia River but did note that "the number of particles found per square meter of ground surveyed decreases as one travels downstream from the reactor areas" (Sula 1980, p. 36).

The next attempt to measure these particles came in 1993 (Cooper and Woodruff 1993). Although the area surveyed was somewhat less than that surveyed by Sula, the 1993 survey also found 11 particles: 10 on one island near the reactors and one further downstream. Two particles were recovered for further analysis. The activities of these two particles were 1.7 and 16 microcuries of cobalt-60.

Most recently, cleanup efforts have been initiated on the island closest to and downstream of the 100-D Area, the island noted in both the Sula and Cooper and Woodruff surveys as having the highest concentration of particles. To date, 103 particles have been recovered, with activities ranging from 0.13 to 22 microcuries of cobalt-60, and minor amounts of other Hanford radionuclides (Wade and Wendling 1994).

Cooper and Woodruff (1993) included an evaluation of the potential for radiation dose from inhalation or ingestion of a discrete particle and from external exposure. It is concluded that, although the possibility of inhalation is remote, the dose-limiting exposure pathway is the inhalation of a particle at the upper end of the range of activity that would remain lodged in the nasal passages for up to 48 hours, resulting in a dose about 10 times the limit for occupational exposure (NCRP 1989).

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6.0 Direct Irradiation from Hanford Facilities

For the last several years, the highest direct radiation exposure rates from Hanford operations observed at locations where the public currently has access have been on the Columbia River along the shoreline at the 100-N Area (e.g., Dirkes et al. 1994). Thermoluminescent dosimeter measurements have been reported annually in the Hanford Site annual environmental reports for this location since 1990. The source of the elevated exposure rates is radiation from facilities located above the river in the 100-N Area. The shoreline is not currently accessible to the public, but the adjacent river is open to the public for recreational uses.

Elevated dose rates at the shoreline are reported in Dirkes et al. (1994, pp. 76, 168). The highest values were measured adjacent to the N Reactor itself and also near the 1301-N Liquid Waste Disposal Facility. The highest readings along the shoreline in 1994 ranged up to about 100 microroentgen/hour in an area where background exposure rates are in the range of 7-10 microroentgen/hour. Dirkes et al. (1994, p. 75) qualify this number to be a probable overestimate. The dose rates have fallen significantly since the closure of the N Reactor in 1988. Dose rates are also elevated near the 100-K Area because of radiologically contaminated materials such as internally contaminated ion-exchange modules used in maintaining water quality in the nearby 105-KE fuel storage basin. A third area of elevated exposure rates is adjacent to the 300 Area.

In 1993, measurements were also made by boat on the Columbia River adjacent to the N Reactor facilities, about 75 meters (250 feet) from the Hanford shoreline (Cooper and Woodruff 1993, p. 4.12-4.13). At this distance, the exposure rates along a 1500-meter (5000-foot) track parallel to the facility ranged from essentially background levels (5 microroentgen/hour) to about 20 microroentgen/hour. Exposure rates on the north shore of the river, across from N Reactor, were all essentially background.

In 1988, EG&G performed an aerial survey of direct exposure rates on the Hanford Site, including the Columbia River and adjacent facilities (EG&G 1990). A low-level, generalized increase in exposure rates is indicated for the shorelines of most of the river. The individual facilities are distinctly noticeable. The 100-N Area evidences the highest exposure rates of river locations.

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7.0 Potential Future Groundwater Sources

Certain contaminants now in soil or groundwater distant from the Columbia River at Hanford may some time in the future pose a source of contamination to the river. Some distant contaminants are essentially certain to reach the river, and others are, at this time, only potential, in part because planned remedial actions will either immobilize or remove them. The contaminants that are already in groundwater are quite likely to reach the Columbia River in the future. Those contaminants contained in Hanford tank farms or burial grounds may not pose a future hazard. For the Columbia River Comprehensive Impact Assessment, only those currently in the groundwater as defined in Section 7.1 are considered. Brief reference is given in Section 7.2 to documentation of the other categories of materials.

7.1 Existing Groundwater Plumes

More than 105 plumes, containing 20 contaminants, are readily observable in groundwater beneath the Hanford Site (Ford 1993; DOE 1994b). A summary of the nature of the existing groundwater contaminant plumes, their general locations, and maximum measured concentrations is given in Table 3.3. Maps of these plumes are provided in Ford (1993), DOE (1994b), and Dirkes et al. (1994). (Note that each of the authors of these reports draws the outlines of the plumes somewhat differently, depending on the purpose of the reports.) An example of one of the most widely dispersed contaminants, nitrate, is shown in Figure 7.1 (Dirkes et al. 1994).

Because those existing contaminant plumes addressed in this section of the report are not in direct contact with the Columbia River, they do not yet constitute a source of contaminants in the river. The window for future concern varies depending both on the location of the plumes and the material in them. Groundwater travel times from the current location to discharge in the river vary by location. Travel times in the 100 Areas generally are less than 1 year. Travel times for groundwater carrying the plumes in the 200 East Area are generally in the range of 20 to 200 years. Travel times for the contaminants in the 600 Area evolving from the Central Landfill Site (see Figure 7.1) are probably about 10 years. Travel times for plumes in the 200-West Area may be as long as 80 to 300 years (Freshley and Graham 1988). All of these estimated times depend on future groundwater conditions and influences such as quantity of water discharged from Hanford operating facilities.

Most of the contaminants listed in Table 3.1 are relatively mobile in groundwater. However, cobalt-60, strontium-90, and cesium-137 have significant chemical interactions with the soil and move much more slowly than the groundwater. (They exist in the groundwater in the 200 Areas because they were essentially injected there directly during waste disposal rather than arriving via percolation from a surface source.) The chemical interactions add to the delay that these materials will experience, particularly those in the distant 200 Areas, before the plumes begin to discharge to the Columbia River. Because the half-lives of cobalt-60 (5.3 years), strontium-90 (28.8 years), and cesium-137 (30.2 years) are relatively short compared to the travel time from the 200 Areas to the Columbia River, they will decay before ever reaching the river. The strontium-90 in the 100 Areas will likely reach the river or continue to enter the river as is the case at the 100-N Area.

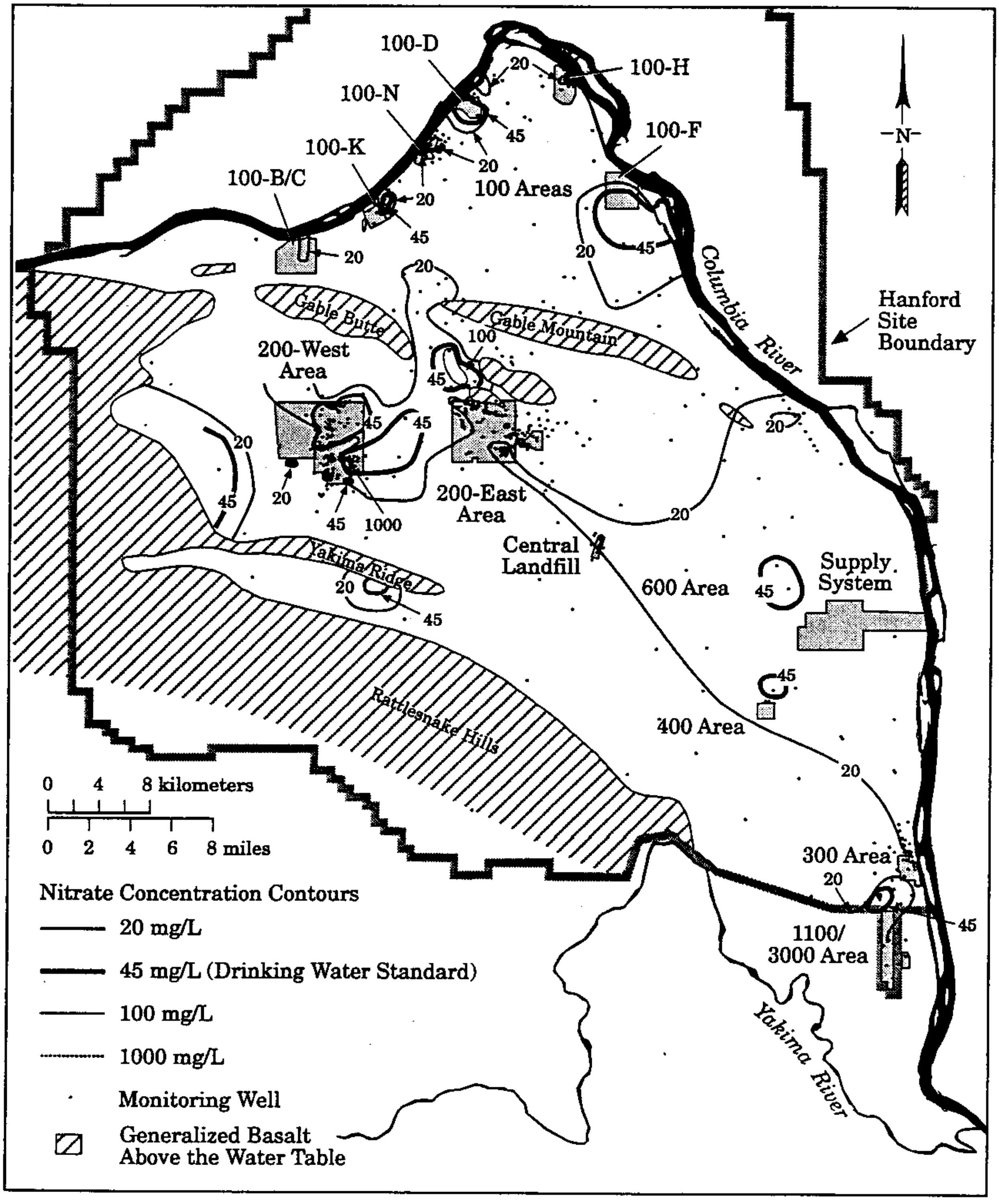

Figure 7.1. Nitrate Plume

Application of the equations and assumptions defined in Section 4.2 to the groundwater plumes results in a series of complementary, but not necessarily intercomparable, screening values for each contaminant. The varying numbers of assumptions and associated varying degrees of conservatism require that each of the screenings be evaluated separately. The combined results of the screenings, however, then define the overall list of contaminants of interest. The complete list of radionuclides and chemicals of concern entered into the project database is presented in Table 3.3. The parameters used in the calculations are presented in Appendix B. The complete numerical results are presented in Appendix C.

The overall screening results for existing groundwater plumes away from the river are given in Table 7.1.

Table 7.1. Contaminants of Potential Interest Identified via Screening of Groundwater Away from the Columbia River

Radionuclide Screening	Carcinogenic Chemical Screening	Hazard Index Screening	Ambient Water Quality Criteria Screening	Aquatic Toxicant Screening
-	Chromium (100 Areas)	Nitrate (100 Areas)	-	Chromium (100 Areas)
-	Chromium (200-West Area)	Nitrate (200-West Area)	-	Nitrate (100 Areas)
-	Chromium (200-East Area)	Nitrate (200-East Area)	-	Fluoride (200-West Area)
-	-	Carbon Tetrachloride (200-West Area)	-	Nitrate (200-West Area)
-	-	-	-	Nitrate (200-East Area)

7.2 Potential Future Groundwater Sources

A very large number of radionuclides and chemicals are contained in Hanford facilities, waste management sites, or other contaminated areas. Remedial actions are planned or under way by the DOE under the provisions of the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al. 1994) to bring the Hanford Site into compliance with the applicable requirements of CERCLA, RCRA, and the Washington State Hazardous Waste Management Act. The DOE program responsible for conducting remedial actions at the Hanford Site is referred to as the Richland Environmental Restoration Project. The scope of the Richland Environmental Restoration Project (DOE 1994h) encompasses the following groups of actions:

- radiation area remedial actions/underground storage tanks (UST)
- RCRA closures

- single-shell tank (SST) closures
- past-practice site operable unit (source and groundwater) remedial actions
- surplus facilities decontamination and decommissioning
- storage and disposal facilities.

Radiation area remedial actions address the management and control of inactive waste sites to minimize the spread of surface soil contamination. The UST program addresses the management of state-regulated, nonradioactive USTs in accordance with Washington State regulations. RCRA closures address actions at certain waste management units classified under RCRA as treatment, storage, and disposal units (TSD). (At Hanford there are over 50 groups of TSD units.) Units subject to regulation as TSDs must either receive a RCRA operating permit or be closed in accordance with the RCRA closure process.

Single-shell tank closures address the development and implementation of final disposal of the 149 SSTs at Hanford. The *Tank Waste Remediation System (TWRS) Environmental Impact Statement (EIS)* is addressing the management, treatment, storage, and disposal of waste in the SSTs. The Notice of Intent for the TWRS-EIS was published in the *Federal Register* on January 28, 1994 (59 FR 4052).

Past-practice operable unit remedial actions address the investigation and remediation of units where waste or other substances have been disposed (intentionally or unintentionally) and are not subject to regulation as TSDs. Over 1000 past-practice units have been identified at the Hanford Site (Ecology et al. 1994).

The Surplus Facilities Decontamination and Decommissioning Program addresses the safe management and final disposition of facilities, such as surplus production reactors and chemical processing buildings, that have been retired and declared surplus. Decontamination and decommissioning of the reactors along the Columbia River are addressed in the *Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington (Final Environmental Impact Statement)* (DOE 1992c). Storage and disposal facilities address the planning, construction, and operation of facilities required for the success of the Richland Environmental Restoration Project (DOE 1994h). These facilities are being addressed individually through CERCLA, RCRA, and NEPA requirements.

Descriptions of the various potential impacts and releases to the Columbia River from the Richland Environmental Restoration Project (DOE 1994h) are provided in the *Hanford Remedial Action Environmental Impact Statement* (DOE 1994g). In addition to the Richland Environmental Restoration Project efforts (DOE 1994h), additional documentation on high-level waste and transuranic waste facilities is covered in the *Final Environmental Impact Statement, Disposal of Hanford Defense High-Level, Transuranic, and Tank Wastes, Hanford Site, Richland, Washington* (DOE 1987).

The future of the many existing waste sites is undergoing review. Very few will remain in their current condition. It is nearly impossible to predict the future impact of these sites until additional planning and activities occur. The reader is directed to the various references for further information on the potential contaminants and their potential future impact on the Columbia River.

8.0 Materials of Additional Public Interest

As information has been released describing past operations and current conditions, public interest in the Hanford Site has increased. Some of the first questions raised during the public review of the *Columbia River Impact Evaluation Plan* (DOE 1993e) were about radiological contamination upriver from the Hanford Site. Questions were asked about the inclusion of chromium, nitrate, and sulfate ions, and the radionuclides cobalt-60 (dispersed as well as discrete particles), rubidium-86, molybdenum-96, ruthenium-106, cesium-137, europium-154, uranium and its decay progeny (specifically radium-226), and plutonium (from fuel failures as well as from decay of neptunium-239).

The majority of these topics have been addressed in this report. Background radiation is attributable to fallout from nuclear weapons testing or naturally occurring radionuclides: potassium-40, radium, tritium (hydrogen-3), thorium, and uranium. In fact, at background levels, it is possible to calculate that nearly 90,000 kilograms (100 tons) of uranium from natural sources alone pass the Hanford Site in the Columbia River every year. The isotope rubidium-86 has an 18-day half-life, and any released from historical Hanford operations would have long ago decayed. Molybdenum-96 is a stable isotope and, therefore, is not radioactive. The half-life of ruthenium-106 (367-day half-life) is similarly short. The half-lives of uranium isotopes are all in excess of 100,000 years (uranium-238, the progenitor of radium-226, has a half-life of 4.5 billion years), and no appreciable decay or progeny accumulation is expected to have occurred. During Hanford operations, about 6.3 million curies of neptunium-239 were released to the Columbia River (Heeb 1994, p. vii). All of that has now decayed into plutonium-239. Because each atom of neptunium becomes one atom of plutonium following the decay, there are no more atoms of plutonium in the river than there were neptunium atoms released. By ratio of the decay constants, that is shown to be no more than 1.7 curies of plutonium-239. Extremely low levels of plutonium have been measured in the sediment behind McNary Dam, enriched by about 30 percent in plutonium-239 over what would be expected from background radiation derived from global fallout.

Public meetings were held in December 1993 and summer 1994 regarding the CRCIA efforts. At these meetings, questions were asked about tritium (hydrogen-3), iodine-129, and uranium. Each of these contaminants has been addressed in this report.

A report produced by a public interest group provides details on Hanford contamination by arsenic, carbon tetrachloride, chloroform, chromium, cyanide, iodine-129, nitrate, plutonium, strontium-90, technetium-99, trichloroethylene, tritium (hydrogen-3), and uranium (Columbia River United circa 1994). All of these contaminants have been addressed by the CRCIA Project and the results presented in this report (see Appendix A).

Iodine-129, plutonium, technetium-99, tritium (hydrogen-3), uranium, and volatile organic compounds (e.g., chloroform and trichloroethylene) are routinely analyzed in Columbia River water samples by the Surface Environmental Surveillance Project (SESP) and the concentrations and resulting exposures reported annually (e.g., Dirkes et al. 1994). Currently, radiation doses to maximally exposed off-site individuals via the river pathway are estimated to be 0.01 mrem/year (Dirkes et al. 1994, p. 220), corresponding to a maximum individual risk of approximately 10^{-8} per year (a probability of an additional fatal cancer of 1 in 100,000,000). The concentrations of volatile organics are near or below detection levels.

Of the contaminants of potential concern raised by the public, some are of concern, but several would have been eliminated by the screening process because they are shown to be of minimal potential hazard. However, those of continued public interest will continue to be evaluated in the CRCIA Project.

These contaminants of probable continued public interest are

- chloroform
- cyanide
- iodine-129
- plutonium-239/240
- technetium-99
- trichloroethylene
- tritium (hydrogen-3)
- uranium.

9.0 Conclusions

More than 600 different radionuclides or chemicals have been sought in Hanford-related environmental samples. A large number of potential contaminants have never been detected in the Hanford/Columbia River environments. For the roughly 100 compounds that have been detected at some level, screening on the basis of potential impact on human health or the health of Columbia River ecosystems has been performed. Several different types of screenings were employed. The results were consistent in that the same compounds were identified numerous times by the various screenings. Application of the screenings for contaminants within 150 meters (500 feet) of the Columbia River yields a list of 20 contaminants of concern, plus direct irradiation. These contaminants are given in the first column of Table 9.1.

Existing Hanford groundwater contamination farther than 150 meters (500 feet) away from the Columbia River has also been addressed. The contaminants identified by the screening process (second column of Table 9.1) are not yet entering the Columbia River but have the potential to do so within 10 to 200 years (Freshley and Graham 1988). Two contaminants (chromium and nitrate) are common with those identified as being already in or near the river, and two (carbon tetrachloride and fluoride) are unique. Continued evaluation of the contaminants of concern (first column of Table 9.1) should cover most of the potential risk from the distant plumes.

Although the screenings did not indicate a potential risk, several potential or existing contaminants are of high interest to the public (third column in Table 9.1). Essentially all of these are the object of ongoing evaluation by SESP conducted by PNL at Hanford. The CRCIA Project should remain current on SESP activities and include SESP results in all project reports.

Each of the identified contaminants can be considered to have resulted from the past plutonium-production operations at Hanford. The radionuclides on the list generally represent those identified with river water or Hanford Reach sediment. The radionuclides resulted from activation of materials in the old production reactors. Although it is likely that the cesium isotopes are related to global fallout (Dirkes et al. 1994). Most of the metals identified in Hanford groundwater or sediment can be related to various Hanford operations in the 100 Areas. The PCB, Arochlor 1248, is used in equipment and the insecticide, Chlordane, has been used in Hanford facilities, but both are still essentially associated with soil near the river. The nitrate groundwater plumes result from past Hanford operations in the 100 and 200 Areas.

The reduction from more than 600 potential chemicals of concern to the final list of 20, plus direct irradiation, was based on several complementary screening techniques and illustrates that future sampling and environmental analyses are both possible and tractable for the CRCIA Project.

Table 9.1. List of Identified Contaminants of Concern[(a)]

In Columbia River, Groundwater,[(b)] Sediment, and Soil	Groundwater Plumes Away from the Columbia River[(c)]	Continued Public Interest
Antimony	Carbon Tetrachloride	Chloroform
Arochlor 1248 (PCB)	Fluoride	Cyanide
Arsenic		Iodine-129
Cesium-134		Plutonium-239/240
Cesium-137		Technetium-99
Chlordane		Trichloroethylene
Chromium[(d)]		Tritium (Hydrogen-3)
Cobalt-60/particles		Uranium
Copper		
Diesel Fuel		
Europium-152		
Europium-154		
Lead		
Manganese		
Mercury		
Nitrate/nitrite[(d)]		
Phosphate		
Silver Chloride		
Strontium-90		
Zinc		

(a) Direct irradiation is also identified as being of concern.
(b) Hanford groundwater within 150 meters (500 feet) of the Columbia River.
(c) Hanford groundwater farther than 150 meters (500 feet) from the Columbia River.
(d) These contaminants are also of concern in groundwater plumes away from the Columbia River but are not repeated in that list to avoid duplication.

10.0 Perspective

The identification of the radionuclides and chemicals of concern to the CRCIA Project should not imply that each or all of these compounds is necessarily a contamination or exposure problem for those who live downstream or the ecosystem of the Columbia River. The screening and selection process described in this report is a conservative (cautious) process designed to focus the resources of the project on those contaminants with potential risk.

Recent sampling has been performed in sediment of the Snake and Columbia Rivers as part of the studies underway concerning reservoir drawdowns for enhancement of salmon stocks. A study by Pinza et al. (1992) included grain size, total organic carbon, total volatile solids, ammonia, phosphorus, sulfides, oil and grease, total petroleum hydrocarbons, metals, polynuclear aromatic hydrocarbons, pesticides, PCBs, and 21 types of polychlorinated dibenzodioxins and dibenzofurans. Samples were taken from the Columbia River at the Port of Kennewick, the Boise Cascade facility below the confluence of the Snake and Columbia Rivers, and at Wallula Gap, as well as from 24 stations on the Snake River.

The study by Pinza et al. (1992) found most measured concentrations of all contaminants to be quite low in Columbia River sediment downstream of Hanford. The concentrations in this CRCIA Project report show most metals in Columbia River sediment to be within the ranges found by Pinza et al. (1992) in Snake River sediment. The few exceptions never differed from the extremes of the range found in the Snake River by more than a factor of 2. One of the pesticides identified by the CRCIA Project as of potential concern, chlordane, was undetected by Pinza et al. (1992) in Columbia River sediment. The PCB, Arochlor 1248, identified by the CRCIA Project as of potential concern was also undetected by Pinza et al. (1992) in Columbia River sediment. The two polynuclear aromatic hydrocarbons discussed in Section 4.4 of this CRCIA report, benzo(a)pyrene and indeno(1,2,3-cd) pyrene, were undetected by Pinza et al. (1992) at Kennewick or Wallula Gap. The frequent inability to detect contaminants at the Boise Cascade facility make it impossible to make a comparison at that location. Petroleum products measured at Kennewick were the lowest found by Pinza et al. (1992) at any location.

Contaminants in the Columbia River, groundwater, sediment, and soil may have potential for impacts on human or ecological health in areas immediately adjacent to the Hanford shorelines, or throughout the Hanford Reach. However, it is evident from the results presented by Pinza et al. (1992) that Columbia River concentrations are similar to those in other rivers not associated with Hanford releases. Whereas Pinza et al. (1992) sampled for non-radionuclides, Wells (1994) examined data for radionuclides and concluded that the potential risk is lower than that allowed by the federal drinking water standards.

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11.0 References

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Appendix A

Complete List of Analytes Evaluated at Hanford

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Appendix A

Complete List of Analytes Evaluated at Hanford

Table A.1 provides a complete listing of all radionuclides and chemicals for which monitoring has been reported in the reviewed literature of samples from the Columbia River and groundwater in the Hanford Site 100, 300, and 1100 Areas within 150 meters (500 feet) of the Columbia River. For those contaminants which had a detected level, the highest concentration reported is listed. A total of 568 analytes are listed. The 73 analytes for which detected levels were reported are listed in Table 3.1.

Table A.2 provides a complete listing of all radionuclides and chemicals for which monitoring has been reported in the reviewed literature of samples from soil and sediment in the Hanford Site 100, 300, and 1100 Areas. For those contaminants which had a detected level, the highest concentration reported is listed. A total of 560 analytes are listed. The 92 analytes for which detected levels were reported are listed in Table 3.2.

Table A.3 provides a listing of the major radionuclides and chemicals for which monitoring has been reported in the reviewed literature of samples from groundwater in the Hanford Site 100, 200, and 600 Areas farther than 150 meters (500 feet) away from the Columbia River. The listing is not comprehensive for all analytes, as described in Section 7.0.

The following abbreviations are used in the tables. All units are as reported in the reviewed literature. The column headings, such as 100-KR-4, refer to sampling locations at operable units, described in Section 2.0.

aCi/L	=	attocuries per liter (one one-millionth of a pCi/L).
CAS#	=	Chemical Abstract Service number, a unique numerical identifier for chemicals.
HEIS	=	Hanford Environmental Information System database.
μg/kg	=	micrograms per kilogram.
μg/L	=	micrograms per liter.
mg/kg	=	milligrams per kilogram.
ND	=	not detected in sample; not all data compilers used this convention; some analytes show no entry where an ND is appropriate.
pCi/kg	=	picocuries per kilogram.
pCi/L	=	picocuries per liter.
ppb	=	parts per billion.
SD	=	sediment.
SW	=	surface water.
w/Pu239	=	concentration included in the value reported for plutonium-239.
w/U233	=	concentration included in the value reported for uranium-233.
*	=	laboratory results marked as suspect data (see Section 4.4).

Table A.1. Radionuclide and Chemical Activity/Concentrations in the Columbia River and Groundwater Near the Columbia River

					GROUNDWATER								COLUMBIA RIVER	
	Name of Analyte	CAS #	Background (a)	Background Reference	HEIS (DOE 1994c)	100-KR-4 (DOE 1994f)	100-HR-3 (DOE 1993d)	100-BC-5 (DOE 1993a)	100-N (Hartman & Lindsey 1993)	1100 Area (Law 1990)	300-FF-1 (DOE 1990b)	300-FF-5 (DOE 1990a)	300-FF-5 (DOE 1990a)	Richland Pumphouse (c)
1	ACENAPHTHENE	83-32-9						ND		ND		ND		
2	ACENAPHTHYLENE	208-96-8						ND		ND		ND		
3	ACETONE	67-64-1	ND (SW)	Dirkes et al. 1993	30 μg/L			26 μg/L		ND		ND	ND	11 μg/L
4	ACETOPHENONE									ND				
5	ACETONITRILE									ND				
6	ACETYLAMINOFLUORENE, 2-									ND				
7	ACETYL-2-THIOUREA, 1-									ND				
8	ACRYLAMINDE									ND				
9	ACROLEIN	107-02-8								ND				
10	ACRYLONITRILE	107-13-1								ND				
11	ACTINIUM 227	14952-40-0												
12	ALDRIN	309-00-2								ND		ND		
13	ALLYL CHLORIDE													
14	ALLYL ALCOHOL									ND				
15	ALPHA, ALPHA-DIMETHYLPHENETHYLA									ND				
16	ALPHA-BHC	319-84-6								ND		ND		
17	ALPHA-CHLORDANE	5103-71-9								ND		ND		
18	ALUMINUM	7429-90-5	< 200 ppb	DOE 1992b, HEIS	1000 μg/L				400 ppb	ND	1210 μg/L	4810 μg/L	ND	
19	ALUMINUM NITRATE	13473-90-0												
20	ALUMINUM SULFATE	10043-01-3												
21	AMERICIUM 241	7440-35-9						0.021 pCi/L						
22	AMERICIUM 242M	13981-54-9												
23	AMERICIUM 243	14993-75-0												
24	AMINOBYPHENYL, 4-									ND				
25	(AMINOMETHYL)-3-1SOXAZOLOL, 5-									ND				
26	AMITROLE									ND				
27	AMMONIA	7664-41-7			70 μg/L								ND	
28	AMMONIUM	14798-03-9	120 ppb	DOE 1992b					300 ppb	ND	1630 μg/L			
29	AMMONIUM ACETATE	631-61-8												
30	AMMONIUM CARBONATE	506-87-6												
31	AMMONIUM CHLORIDE	12125-02-9												
32	AMMONIUM FLUORIDE	12125-10-8												
33	AMMONIUM NITRATE	6484-52-2												
34	AMMONIUM OXALATE	1113-38-8												
35	AMMONIUM SILICOFLUORIDE	1309-32-6												
36	AMMONIUM SULFATE	7783-20-2												
37	AMMONIUM SULFITE	10196-04-0												
38	AMMONIUM THIOSULFATE	7783-18-8												
39	ANILINE	62-53-3								ND		ND		
40	ANTHRACENE	120-12-7								ND		ND		
41	ANTIMONY	7440-36-0	ND (SW)	Dirkes et al. 1993	80 μg/L					ND		47 μg/L	ND	ND
42	ANTIMONY (III) NITRATE	20328-96-5												
43	ANTIMONY 124	7440-36-0												
44	ANTIMONY 125	14234-35-6			20 pCi/L							ND	ND	
45	ANTIMONY CHLORIDE	10025-9-19												
46	ARAMITE									ND				
47	AROCHLOR-1016									ND				
48	AROCHLOR-1221	11104-28-2								ND		ND		
49	AROCHLOR-1232	11141-16-5								ND		ND		
50	AROCHLOR-1242									ND				
51	AROCHLOR-1248									ND				
52	AROCHLOR-1254									ND				
53	AROCHLOR-1260	11096-82-5								ND		ND		
54	AROCLOR 1016 (PCB)	12674-11-2										ND		
55	AROCLOR 1242 (PCB)	53469-21-9										ND		
56	AROCLOR 1248 (PCB)	12672-29-6										ND		
57	AROCLOR 1254 (PCB)	11091-69-1										ND		
58	ARSENIC	7440-38-2	10 ppb	DOE 1992b	10 μg/L	10.4 μg/L			9 ppb	ND	17 μg/L	14.5 μg/L	3.4 μg/L	
59	ARSENIC TRIOXIDE	1327-53-3												
60	ASBESTOS	332-21-4												
61	AURAMINE									ND				
62	BARIUM	7440-39-3	68.5 ppb	DOE 1992b	100 μg/L		140 μg/L		140 ppb	58ppb	719 μg/L	206 μg/L	48.2 μg/L	29 μg/L
63	BARIUM 133	13981-41-4												
64	BARIUM 140	7440-39-3												
65	BARIUM NITRATE	10022-31-8												

Table A.1. (contd)

					GROUNDWATER								COLUMBIA RIVER	
									100-N					
	Name of Analyte	CAS #	Background (a)	Background Reference	HEIS (DOE 1994c)	100-KR-4 (DOE 1994f)	100-HR-3 (DOE 1993d)	100-BC-5 (DOE 1993a)	(Hartman & Lindsey 1993)	1100 Area (Law 1990)	300-FF-1 (DOE 1990b)	300-FF-5 (DOE 1990a)	300-FF-5 (DOE 1990a)	Richland Pumphouse (c)
66	BENZ[C]ACRIDINE									ND				
67	BENZENE	71-43-2						ND	ND (d)	ND		ND	ND	ND
68	BENZENETHIOL									ND				
69	BENZO(G,H,I)PERYLENE	191-24-2						ND		ND		ND		
70	BENZO(J)FLUORANTHENE									ND				
71	BENZO[a]ANTHRACENE	56-55-3						ND		ND		ND		
72	BENZIDINE									ND				
73	BENZO[a]PYRENE	50-32-8						ND		ND		ND		
74	BENZO[b]FLUORANTHENE	205-99-2						ND		ND		ND		
75	BENZO[K]FLUORANTHENE	207-08-9						ND		ND		ND		
76	BENZOIC ACID	65-85-0										ND		
77	BENZYL ALCOHOL	100-51-6								ND		ND		
78	BENZYL CHLORIDE									ND				
79	BERYLLIUM	7440-41-7	ND (SW)	Dirkes et al. 1993	1 μg/L				6 ppb	5ppb		1.4 μg/L	ND	ND
80	BERYLLIUM 7	7440-41-7	< 5 ppb	DOE 1992b										
81	BETA-BHC	319-85-7								ND		ND		
82	BIS(2-CHLORO-1-METHYLETHYL)ETH									ND				
83	BIS(2-CHLOROETHOXY)METHANE	111-91-1								ND		ND		
84	BIS(2-CHLOROETHYL)ETHER	111-44-4								ND		ND		
85	BIS(2-CHLOROISOPROPYL)ETHER	39638-32-9								ND		ND		
86	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7			50 μg/L			11 μg/L			50 μg/L	ND		
87	BISMUTH	7440-69-9	< 5 ppb	DOE 1992b										
88	BISMUTH 212	14913-49-6												
89	BISMUTH 214	14733-03-0												
90	BORON	7440-42-8	< 100 ppb	DOE 1992b						64ppb				
91	BROMIDE		ND (SW)	Dirkes et al. 1993					ND	ND				ND
92	BROMOACETONE									ND				
93	BROMODICHLOROMETHANE	75-27-4						ND		ND		ND	ND	
94	BROMOFORM	75-25-2						ND		ND		ND	ND	
95	BROMOMETHANE	74-83-9						ND				ND	ND	
96	BROMOPHENYL-PHENYLETHER, 4-	101-55-3								ND		ND		
97	BUTANOL, 1-	71-36-3	ND (SW)	Dirkes et al. 1993						ND		ND	ND	ND
98	BUTANONE	78-93-3						ND				ND		
99	BUTANONE, 2-	78-93-3											ND	
100	BUTYL BENZYL PHTHALATE	85-68-7						ND		ND				
101	BUTYNOL, 1-									ND				
102	CADMIUM	7440-43-9	< 10 ppb	DOE 1992b	10 μg/L				31 ppb	ND	6.6 μg/L	3 μg/L	ND	ND
103	CADMIUM 109	14109-32-1												
104	CADMIUM NITRATE	10325-97-7												
105	CALCIUM	7440-70-2	63600 ppb	DOE 1992b	100000 μg/L	94600 μg/L	130000 μg/L		302000ppb	81400 ppb	21200 μg/L	76600 μg/L	35900 μg/L	19000 μg/L
106	CALCIUM 41	14092-95-6												
107	CALCIUM BICARBONATE	1317-65-3												
108	CARBAZOLE	86-74-8										ND		
109	CARBAZOLE, 9H-	86-74-8						ND						
110	CARBON 14	14762-75-5			200 pCi/L	23000 pCi/L		110 pCi/L						
111	CARBON DISULFIDE	75-15-0						ND		ND		ND	ND	
112	CARBON TETRACHLORIDE	56-23-5	ND (SW)	Dirkes et al. 1993				ND		ND		ND	ND	ND
113	CARBOPHENOTHION									ND				
114	CERIUM	7440-45-1												
115	CERIUM 141	13967-74-3												
116	CERIUM 144	14762-78-8	ND (SW)	Dirkes 1994										ND
117	CESIUM 134	13967-70-9	ND (SW)	Dirkes et al. 1994				ND				ND	ND	0.012 pCi/L
118	CESIUM 135	15726-30-4												
119	CESIUM 137	10045-97-3	ND (SW)	Dirkes et al. 1994	0.5 pCi/L			ND				ND	ND	0.13 pCi/L
120	CHLOR-2, 3-EPOXYPROPANE, 1-									ND				
121	CHLORDANE	57-74-9								ND		ND		
122	CHLORIDE	16887-00-6	8690 ppb (b)	DOE 1992b	30000 μg/L				18000 ppb	43400 ppb	122000 μg/L	ND	ND	870 μg/L
123	CHLORINE	7782-50-5												
124	CHLORNAPHAZINE									ND				
125	CHLOROALKYL ETHERS									ND				
126	CHLOROANILINE, 4-	106-47-8										ND		
127	CHLOROBENZENE	108-90-7						ND		ND		ND	ND	
128	CHLOROBENZILATE									ND				
129	CHLORODIBROMOMETHANE	124-48-1												
130	CHLOROETHANE	75-00-3						ND		ND		ND	ND	

Table A.1. (contd)

					GROUNDWATER								COLUMBIA RIVER	
	Name of Analyte	CAS #	Background (a)	Background Reference	HEIS (DOE 1994c)	100-KR-4 (DOE 1994f)	100-HR-3 (DOE 1993d)	100-BC-5 (DOE 1993a)	100-N (Hartman & Lindsey 1993)	1100 Area (Law 1990)	300-FF-1 (DOE 1990b)	300-FF-5 (DOE 1990a)	300-FF-5 (DOE 1990a)	Richland Pumphouse (c)
131	CHLOROETHOXY ETHENE, 2-											ND	ND	
132	CHLOROETHYLVINYL ETHER, 2-	110-75-8								ND				
133	CHLOROFORM	67-66-3	ND (SW)	Dirkes et al. 1993	10 µg/L	17 µg/L		ND		8 ppb	42 µg/L	18 µg/L	ND	ND
134	CHLOROMETHANE	74-87-3						ND				ND	ND	
135	CHLOROMETHYL METHYL ETHER									ND				
136	CHLOROMETHYLPHENOL, 4-3-	35421-08-0										ND		
137	CHLORONAPHTHALENE, 2-	91-58-7						ND		ND		ND		
138	CHLOROPHENOL, 2-	95-57-8						ND		ND		ND		
139	CHLOROPHENYL-PHENYL ETHER, 4-	7005-72-3										ND		
140	CHLOROPROPIONITRILE, 3-									ND				
141	CHROMIC ACID	7738-94-5												
142	CHROMIUM	7440-47-3	< 30 ppb	DOE 1992b	500 µg/L	1950 µg/L	490 µg/L		180 ppb	30 ppb	257 µg/L	363 µg/L	ND	22 µg/L
143	CHROMIUM (IV)	15723-28-1												
144	CHROMIUM (VI)	18540-29-9												
145	CHROMIUM 51	14392-02-0						ND				ND	ND	
146	CHROMIUM NITRATE	13548-38-4												
147	CHROMIUM SULFATE	10101-53-8												
148	CHRYSENE	218-01-9						ND		ND		ND		
149	CITRUS RED									ND				
150	COBALT	7440-48-4	ND (SW)	Dirkes et al. 1993	8 µg/L				ND	ND		5.4 µg/L	ND	ND
151	COBALT 58	13981-38-9												
152	COBALT 60	10198-40-0	ND (SW)	Dirkes et al. 1994	10 pCi/L			ND	140 pCi/L		64 pCi/L	3.49 pCi/L	ND	0.011 pCi/L
153	COPPER	7440-50-8	< 30 ppb	DOE 1992b	60 µg/L		40 µg/L		91 ppb	ND	516 µg/L	14.7 µg/L	ND	22µg/L
154	COPPER NITRATE	3251-23-8												
155	COPPER SULFATE	7558-98-7												
156	CRESOLS									ND				
157	CROTONALDEHYDE									ND				
158	CURIUM 242	15510-73-3												
159	CURIUM 244	13981-15-2												
160	CURIUM 245	15621-76-8												
161	CYANIDE	57-12-5			20 µg/L					ND	11 µg/L	21.1 µg/L	ND	
162	CYCLOHEXYL-4,6-DINITROPHENOL, 2-									ND				
163	D, 2,4-									ND				
164	DDD, 4,4'-	72-54-8								ND		ND		
165	DDE, 4,4'-	72-55-9								ND		ND		
166	DDT, 4,4'-	50-29-3								ND		ND		
167	DELTA-BHC	319-86-8								ND		ND		
168	DIALLATE									ND				
169	DI-N-BUTYLPHTHALATE	84-74-2						ND		ND		ND		
170	DI-N-PROPYLNITROSAMINE									ND				
171	DI-N-OCTYLPHTHALATE	117-84-0						ND		ND		ND		
172	DIBENZ(a,h)ACRIDINE									ND				
173	DIBENZ(a,j)ACRIDINE									ND				
174	DIBENZ(A,G)ANTHRACENE	53-70-3												
175	DIBENZ(A,H)ANTHRACENE	53-70-3						ND		ND		ND		
176	DIBENZO(c,g)CARBAZOLE, 7H-									ND				
177	DIBENZO(a,e)PYRENE									ND				
178	DIBENZO(a,h)PYRENE									ND				
179	DIBENZO(a,i)PYRENE									ND				
180	DIBENZOFURAN	132-64-9						ND		ND		ND		
181	DIBROMO-3-CHLOROPROPANE, 1,2-									ND				
182	DIBROMOCHLOROMETHANE	124-48-1						ND		ND		ND	ND	
183	DIBROMOETHANE, 1,2-									ND				
184	DIBROMOMETHANE									ND				
185	DIBUTYLPHOSPHATE									ND				
186	DICHLORO-2-BUTENE, 1,4-									ND				
187	DICHLOROBENZENE, p-		ND (SW)	Dirkes et al. 1993						ND				ND
188	DICHLOROBENZENE, 1,2-	95-50-1						ND		ND		ND		
189	DICHLOROBENZENE, 1,3-	541-73-1						ND		ND		ND		
190	DICHLOROBENZENE, 1,4-	106-46-7						ND				ND		
191	DICHLOROBENZIDINE, 3,3'	91-94-1						ND		ND		ND		
192	DICHLORODIFLUOROMETHANE	75-71-8								ND				
193	DICHLOROETHANE, 1,1-	75-34-3	ND (SW)	Dirkes et al. 1993				ND		ND		ND	ND	ND
194	DICHLOROETHANE, 1,2-	107-06-2	ND (SW)	Dirkes et al. 1993				ND		ND		ND	ND	ND
195	DICHLOROETHYLENE, 1,1-	75-35-4						ND		ND		ND	ND	

Table A.1. (contd)

					GROUNDWATER								COLUMBIA RIVER	
									100-N					
	Name of Analyte	CAS #	Background (a)	Background Reference	HEIS (DOE 1994c)	100-KR-4 (DOE 1994f)	100-HR-3 (DOE 1993d)	100-BC-5 (DOE 1993a)	(Hartman & Lindsey 1993)	1100 Area (Law 1990)	300-FF-1 (DOE 1990b)	300-FF-5 (DOE 1990a)	300-FF-5 (DOE 1990a)	Richland Pumphouse (c)
196	DICHLOROETHYLENE, 1,2-	540-59-0	ND (SW)	Dirkes et al. 1993	200 µg/L			ND				150 µg/L	ND	ND
197	DICHLOROETHYLENE, 1,2-cis-	156-59-2												
198	DICHLOROETHYLENE, 1,2-trans-	156-60-5								ND	72 µg/L	0.13 mg/L		
199	DICHLOROPHENOL, 2,4-	120-83-2						ND		ND		ND		
200	DICHLOROPHENOL, 2,6-	87-65-0								ND		ND		
201	DICHLOROPHENOXYACETIC ACID, 2,4-	94-75-7										ND		
202	DICHLOROPROPANE, 1,2-	78-87-5						ND		ND		ND	ND	
203	DICHLOROPROPENE, 1,3-									ND				
204	DICHLOROPROPENE, 1,3-cis-	10061-02-6						ND				ND	ND	
205	DICHLOROPROPENE, 1,3-trans-	10061-01-5						ND				ND	ND	
206	DIELDRIN	60-57-1								ND		ND		
207	DIESEL FUEL													
208	DIETHYL-0,2-PYRAZINYL PHOSPHATE, 0,0-									ND				
209	DIETHYLPHTHALATE	84-66-2						ND		ND		ND		
210	DIETHYLSTILBESTEROL									ND				
211	DIHYDROSAFROLE									ND				
212	DIMETHOATE									ND				
213	DIMETHOXYBENZIDINE, 3,3'-									ND				
214	DIMETHYLBENZ(a)ANTHRACENE, 7,12-									ND				
215	DIMETHYLBENZIDINE, 3,3'-									ND				
216	DIMETHYLHYDRAZINE, 1,1-									ND				
217	DIMETHYLHYDRAZINE, 1,2-									ND				
218	DIMETHYLPHENOL, 2,4-	105-67-9						ND				ND		
219	DIMETHYLPHTHALATE	131-11-3						ND		ND				
220	DINITRO-2-METHYLPHENOL, 4,6-	534-42-1										ND		
221	DINITROBENZENE									ND				
222	DINITRO-O-CRESOL, 4,6- and salts									ND				
223	DINITROPHENOL, 2,4-	51-28-5						ND		ND		ND		
224	DINITROPHENOL, P-									ND				
225	DINITROTOLUENE, 2,4-	121-14-2						ND		ND		ND		
226	DINITROTOLUENE, 2,6-	606-20-2						ND		ND		ND		
227	DINOSEB									ND				
228	DIOXANE									ND				
229	DIPHENYLAMINE									ND				
230	DIPHENYLHYDRAZINE, 1,2-									ND				
231	DISULFOTON									ND				
232	ENDOSULFAN I	959-98-8								ND		ND		
233	ENDOSULFAN II	33213-65-9								ND		ND		
234	ENDOSULFAN SULFATE	1031-07-8								ND		ND		
235	ENDRIN	72-20-8								ND		ND		
236	ENDRIN ALDEHYDE	7421-93-4										ND		
237	ENDRIN KETONE	53494-70-5										ND		
238	ETHANOL									ND				
239	ETHYLBENZENE	100-41-4						ND		ND			ND	
240	ETHYLCARBAMATE									ND				
241	ETHYL CYANIDE									ND				
242	ETHYLENE GLYCOL									ND				
243	ETHYLENE OXIDE									ND				
244	ETHYLENEIMINE									ND				
245	ETHYLENETHIOUREA									ND				
246	ETHYLMETHACRYLATE									ND				
247	ETHYL METHANESULFONATE									ND				
248	EUROPIUM 152	14683-23-9						ND				ND	ND	
249	EUROPIUM 154	15585-10-1			2 pCi/L			ND				ND	ND	
250	EUROPIUM 155	14391-16-3												
251	FERRIC NITRATE	10421-48-4												
252	FERRIC SULFATE	10028-22-5												
253	FERROCYANIDE	13408-63-4												
254	FERROUS AMMONIUM SULFATE	7783-85-9												
255	FERROUS SULFATE	7720-78-7												
256	FLUORANTHENE	206-44-0						ND		ND		ND		
257	FLUORENE	86-73-7						ND		ND		ND		
258	FLUORIDE	7782-41-4	160 µg/L (SW)	Dirkes et al. 1993	1000 µg/L				1600 ppb	ND	2080 µg/L	ND	ND	150 µg/L
259	FLUORINE		775 ppb	DOE 1992b										
260	FLUOROTRICHLOROMETHANE	75-69-4												

Table A.1. (contd)

					GROUNDWATER								COLUMBIA RIVER	
									100-N					
	Name of Analyte	CAS #	Background (a)	Background Reference	HEIS (DOE 1994c)	100-KR-4 (DOE 1994f)	100-HR-3 (DOE 1993d)	100-BC-5 (DOE 1993a)	(Hartman & Lindsey 1993)	1100 Area (Law 1990)	300-FF-1 (DOE 1990b)	300-FF-5 (DOE 1990a)	300-FF-5 (DOE 1990a)	Richland Pumphouse (c)
261	FORMALIN									ND				
262	FUEL OIL #2	68476-34-6												
263	GAMMA-BHC(LINDANE)	58-89-9								ND		ND		
264	GAMMA-CHLORDANE	5103-74-2										ND		
265	HEPTACHLOR	76-44-8								ND		ND		
266	HEPTACHLOR EPOXIDE	1024-57-3								ND		ND		
267	HEPTACHLOR EPOXIDE (ENDO)													
268	HEPTACHLOR EPOXIDE (EXO)													
269	HEXACHLOROBENZENE	118-74-1						ND		ND		ND		
270	HEXACHLOROBUTADIENE	87-68-3						ND		ND		ND		
271	HEXACHLOROCYCLOPENTADIENE	77-47-4						ND		ND		ND		
272	HEXACHLOROETHANE	67-72-1						ND		ND		ND		
273	HEXACHLOROPHENE									ND				
274	HEXACHLOROPROPENE									ND				
275	HEXANONE, 2-	591-78-6						ND		ND		ND	ND	
276	HEXYL METHANOATE	629-33-4												
277	HYDRAZINE	302-01-2			7 µg/L					ND				
278	HYDROCARBONS													
279	HYDROCHLORIC ACID	7647-01-0												
280	HYDROCYANIC ACID	74-90-8												
281	HYDROFLUORIC ACID	7664-39-3												
282	HYDROGEN SULFIDE	7783-06-4												
283	INDENO(1,2,3-CD)PYRENE	193-39-5						ND		ND		ND		
284	IODINE 129	15046-84-1	5 aCi/L (SW)	Dirkes et al. 1994								ND	ND	160 pCi/L
285	IODINE 131	10043-66-0	ND (SW)	Dirkes et al. 1994										ND
286	IODOMETHANE									ND				
287	IRON	7439-89-6	86 ppb (b)	DOE 1992b			5400 µg/L		37300 ppb	394 ppb	8300 µg/L	9570 µg/L	463 µg/L	92 µg/L
288	IRON 59							ND				ND	ND	
289	ISOBUTYL ALCOHOL									ND				
290	ISODRIN									ND				
291	ISOPHORONE	78-59-1						ND		ND		ND		
292	ISOSAFROLE									ND				
293	KEPONE									ND				
294	KEROSENE	8008-20-6								ND				
295	KRYPTON 85													
296	LANTHANUM	7439-91-0												
297	LEAD	7439-92-1	< 5 ppb	DOE 1992b	40 µg/L		5.1 µg/L		18 ppb	ND	173 µg/L	5.8 µg/L	ND	
298	LEAD 210	14255-04-0												
299	LEAD 212	15092-94-1												
300	LEAD NITRATE	10099-74-8												
301	LITHIUM	7439-93-2								ND				
302	LITHIUM CHLORIDE	7447-41-8												
303	MALEIC HYDRIZIDE									ND				
304	MALONONITRILE									ND				
305	MAGNESIUM	7439-95-4	16480 ppb	DOE 1992b	30000 µg/L		23000 µg/L		55000 ppb	15200 ppb	11800 µg/L	14600 µg/L	9860 µg/L	4200 µg/L
306	MANGANESE	7439-96-5	24.5 ppb (b)	DOE 1992b	400 µg/L	69.6 µg/L	180 µg/L		212 ppb	21 ppb	191 µg/L	332 µg/L	22.8 µg/L	11 µg/L
307	MANGANESE 54	13966-31-9												
308	MELPHALAN									ND				
309	MERCURIC NITRATE	10045-95-0												
310	MERCURIC THIOCYANATE	592-85-8												
311	MERCURY	7439-97-6	< 0.1 ppb	DOE 1992b	0.2 µg/L				ND	ND	8.9 µg/L	ND	ND	ND
312	METHACRYLONITRILE									ND				
313	METHANAL	50-00-0												
314	METHANETHIOL									ND				
315	METHANOL	67-56-1												
316	METHAPYRILENE									ND				
317	METHOLONYL									ND				
318	METHOXYCHLOR	72-43-5								ND		ND		
319	METHYLAZIRIDINE, 2-									ND				
320	METHYL BROMIDE									ND				
321	METHYL CHLORIDE									ND				
322	METHYL ETHYL KETONE		ND (SW)	Dirkes et al. 1993						ND	18 µg/L			ND
323	METHYL-2-(METHYLTHIO)PROPIO, 2-									ND				
324	METHYL-2-PENTANONE, 4-	108-10-1	ND (SW)	Dirkes et al. 1993				ND		ND		ND	ND	ND
325	METHYLCHOLANTHRENE, 3-									ND				

Table A.1. (contd)

					GROUNDWATER								COLUMBIA RIVER	
	Name of Analyte	CAS #	Background (a)	Background Reference	HEIS (DOE 1994c)	100-KR-4 (DOE 1994f)	100-HR-3 (DOE 1993d)	100-BC-5 (DOE 1993a)	100-N (Hartman & Lindsey 1993)	1100 Area (Law 1990)	300-FF-1 (DOE 1990b)	300-FF-5 (DOE 1990a)	300-FF-5 (DOE 1990a)	Richland Pumphouse (c)
326	METHYLENE BIS (2-CHLOROANIL), 4,4'-									ND				
327	METHYLENE bis(3,4,6-TRICHLOROPHENOL)	70-30-4												
328	METHYLENE CHLORIDE	75-09-2			2 μg/L			ND		ND	3040 μg/L	ND	ND	ND
329	METHYL ISOBUTYL KETONE									ND				
330	METHYLLACTONITRILE, 2-									ND				
331	METHYL METHACRYLATE									ND				
332	METHYL METHANE SULFONATE									ND				
333	METHYLNAPHTHALENE, 2-	91-57-6						ND		ND		ND		
334	METHYL PARATHION									ND				
335	METHYLPHENOL, 2-	95-48-7						ND				ND		
336	METHYLPHENOL, 4-	106-44-5										ND		
337	METHYLPHENOL, 4-CHLORO-3-	59-50-7												
338	METHYLTHIOURACIL									ND				
339	MOLYBDENUM	7439-98-7						ND		ND				
340	MONOBUTYL PHOSPHATE									ND				
341	N,N-DIETHYLHYDRAZINE									ND				
342	N-NITORSODIETHANOLAMINE									ND				
343	N-NITROSODIETHYLAMINE									ND				
344	N-NITROSODIMETHYLAMINE									ND				
345	N-NITROSODI-N-BUTYLAMINE									ND				
346	N-NITROSO-DI-N-PROPYLAMINE	621-64-7						ND				ND		
347	N-NITROSODIPHENYLAMINE	86-30-6						ND		ND		ND		
348	N-NITROSOMETHYLETHYLAMINE									ND				
349	N-NITROSOMETHYLVINYLAMINE									ND				
350	N-NITROSOMORPHOLINE									ND				
351	N-NITROSO-N-METHYL URETHANE									ND				
352	N-NITROSONORNICOTINE									ND				
353	N-NITROSOPIPERIDINE									ND				
354	N-PHENYLTHIOUREA									ND				
355	N-PROPYLAMINE									ND				
356	NAPHTHALENE	91-20-7						ND		ND		ND		
357	NAPTHOQUINONE, 1,4-									ND				
358	NAPHTHYL-2-THIOUREA, 1-									ND				
359	NAPHTHYLAMINE, 1-	91-59-8								ND				
360	NAPHTHYLAMINE, 2-									ND				
361	NEPTUNIUM 237	13994-20-2												
362	NEPTUNIUM 239	13968-59-7												
363	NICKEL	7440-02-0	< 30 ppb	DOE 1992b	100 μg/L	18.7 μg/L			479 ppb	19 ppb	95 μg/L	206 μg/L	ND	31 μg/L
364	NICKEL 59	14336-70-0												
365	NICKEL 63	13981-37-8												
366	NICKEL FERROCYANIDE	14874-78-3												
367	NICKEL NITRATE	13138-45-9												
368	NICKEL SULFATE	7786-81-4												
369	NICOTINIC ACID									ND				
370	NIOBIUM 95	13967-76-5												
371	NITRATE	14797-55-8	12400 ppb	DOE 1992b	90000 μg/L					20300 ppb	82000 μg/L	15.6 mg/L	ND	480 μg/L
372	NITRIC ACID	7697-37-2							1000 ppb	ND				
373	NITRITE	14797-65-0	ND (SW)	Dirkes et al. 1993	60000 μg/L							ND	ND	ND
374	NITRO-O-TOLUIDINE, 5-									ND				
375	NITROANILINE, 2-	88-74-4						ND				ND		
376	NITROANILINE, 3-	99-09-2										ND		
377	NITROANILINE, 4-	100-01-6						ND				ND		
378	NITROANILINE, m-									ND				
379	NITROANILINE, o-									ND				
380	NITROBENZENE	98-95-3						ND				ND		
381	NITROBENZINE									ND				
382	NITROGEN OXIDE	10024-97-2												
383	NITROPHENOL, 2-	88-75-5						ND				ND		
384	NITROPHENOL, 4-	100-02-7						ND				ND		
385	NITROSOPYRROLIDINE									ND				
386	NITROQUINOLINE-1-OXIDE, 4-									ND				
387	O,O,O,-TRIETHYL PHOSPHOROTHIOAT									ND				
388	O-TOLUIDINE HYDROCHLORIDE									ND				
389	ORTHO-PHOSPHATE													
390	OSMIUM													

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Table A.1. (contd)

					GROUNDWATER								COLUMBIA RIVER	
	Name of Analyte	CAS #	Background (a)	Background Reference	HEIS (DOE 1994c)	100-KR-4 (DOE 1994f)	100-HR-3 (DOE 1993d)	100-BC-5 (DOE 1993a)	100-N (Hartman & Lindsey 1993)	1100 Area (Law 1990)	300-FF-1 (DOE 1990b)	300-FF-5 (DOE 1990a)	300-FF-5 (DOE 1990a)	Richland Pumphouse (c)
391	OXYBIS(1-CHLOROPROPANE), 2,2'-													
392	P-BENZOQUINONE									ND				
393	P-CHLORO-M-CRESOL									ND				
394	P-CHLOROANILINE									ND				
395	P-DIMETHYLAMINOAZOBENZENE									ND				
396	P-NITROANILINE									ND				
397	PALLADIUM	7440-05-3												
398	PARALDEHYDE									ND				
399	PARATHION									ND				
400	PCDDs									ND				
401	PCDFs									ND				
402	PENTACHLOROBENZENE									ND				
403	PENTACHLOROETHANE									ND				
404	PENTACHLORONITROBENZENE									ND				
405	PENTACHLOROPHENOL	87-86-5						ND		ND		ND		
406	PHENANTHRENE	85-01-8						ND		ND		ND		
407	PHENACETIN									ND				
408	PHENOL	108-95-2						ND		ND		ND		
409	PHENYLENEDIAMINE									ND				
410	PHORATE									ND				
411	PHOSPHATE	7601-54-9	< 1000 ppb(c)	DOE 1992b	200 μg/L				ND	ND		ND	ND	3240 μg/L
412	PHOSPHORIC ACID	7664-38-2												
413	PHOSPHORUS	7723-14-0												
414	PHOSPHORUS 32													
415	PHTHALIC ACID ESTERS									ND				
416	PICOLINE, 2-									ND				
417	PLUTONIUM 238	13981-16-3	ND (SW)	Dirkes et al. 1994				ND				.01 pCi/L	ND	ND
418	PLUTONIUM 239	15117-48-3			0.03 pCi/L			ND				ND	ND	
419	PLUTONIUM 240	14119-32-5						ND						
420	PLUTONIUM 241	14119-32-6										ND	ND	
421	PLUTONIUM 242	13982-10-0												
422	POLONIUM 210	13981-52-8												
423	POLONIUM 212	15389-34-1												
424	POLONIUM 216	15756-58-8												
425	POLYCHLORINATED BIPHENYLS	1336-36-3												
426	POTASSIUM	7447-40-7	7975 ppb	DOE 1992b	9000 μg/L		9300 μg/L		10100 ppb	8020ppb	11300 μg/L	10200 μg/L	2430 μg/L	690 μg/L
427	POTASSIUM 40							ND				240 pCi/L	ND	
428	POTASSIUM CHLORATE	3811-04-9												
429	POTASSIUM CYANIDE	151-50-8												
430	POTASSIUM DICHROMATE	7778-50-9												
431	POTASSIUM FLUORIDE	7789-23-3												
432	POTASSIUM HYDROXIDE	1310-58-3												
433	POTASSIUM NITRATE	7757-79-1												
434	POTASSIUM PERMANGANATE	7722-64-7												
435	PROMETHIUM 147	7440-12-2												
436	PRONAMIDE									ND				
437	PROPANOL, 1-									ND				
438	PROPIONITRILE									ND				
439	PROPYN-1-OL, 2-									ND				
440	PROTACTINIUM 231	14331-85-2												
441	PROTACTINIUM 233	13981-14-1												
442	PYRENE	129-00-0						ND		ND		ND		
443	PYRIDINE	110-86-1								ND				
444	RADIUM	7440-14-4	0.23 pCi/L	DOE 1992b	0.3 pCi/L					ND		.0825 pCi/L	ND	
445	RADIUM 226	13982-63-3						ND				95 pCi/L	ND	
446	RADIUM 228													
447	RADON 220	22481-48-7												
448	RESERPINE									ND				
449	RESORCINOL									ND				
450	RUTHENIUM 103	13968-53-1			6 pCi/L									
451	RUTHENIUM 106	13967-48-1	ND (SW)	Dirkes et al. 1994	20 pCi/L							34.4 pCi/L	ND	ND
452	SAFROL									ND				
453	SAMARIUM 151	15705-94-3						ND						
454	SCANDIUM 46													
455	SECBUTYL-4,6-DINITROPHENOL									ND		ND		

Table A.1. (contd)

					GROUNDWATER								COLUMBIA RIVER	
	Name of Analyte	CAS #	Background (a)	Background Reference	HEIS (DOE 1994c)	100-KR-4 (DOE 1994i)	100-HR-3 (DOE 1993d)	100-BC-5 (DOE 1993a)	100-N (Hartman & Lindsey 1993)	1100 Area (Law 1990)	300-FF-1 (DOE 1990b)	300-FF-5 (DOE 1990a)	300-FF-5 (DOE 1990a)	Richland Pumphouse (c)
456	SELENIUM	7782-49-2	< 5 ppb	DOE 1992b	4 μg/L				ND	ND		17.2 μg/L	ND	
457	SELENIUM 79	15758-45-9												
458	SELENIUM CHLORIDE	10025-68-0												
459	SELENIUM NITRATE													
460	SILICON		26500 ppb	DOE 1992b						17000ppb				
461	SILVER	7440-22-4	< 10 ppb	DOE 1992b	7 μg/L				ND	ND		10 μg/L	ND	19 μg/L
462	SILVER CHLORIDE	7783-90-6												
463	SILVER NITRATE	7761-88-8												
464	SILVER OXIDE	20667-12-3												
465	SODIUM	7440-23-5	33500 ppb	DOE 1992b	200000 μg/L		200000 μg/L			335000ppb	68300 μg/L	65100 μg/L	13800 μg/L	2200 μg/L
466	SODIUM 22	7440-23-5												
467	SODIUM ALUMINATE													
468	SODIUM CHLORIDE	7647-14-5												
469	SODIUM DICHROMATE	10588-01-9												
470	SODIUM FLUORIDE	7681-49-4												
471	SODIUM HYDROXIDE	1310-73-2												
472	SODIUM HYPOCHLORITE	7681-52-9												
473	SODIUM NITRATE	7631-99-4												
474	SODIUM PHOSPHATE, TRIBASIC	7601-54-9												
475	SODIUM SILICATE	1344-09-8												
476	SODIUM SULFATE	7757-82-6												
477	SODIUM SULFIDE	1313-82-2												
478	SODIUM THIOCYANATE	540-72-7												
479	STRONTIUM	10476-85-4	264.1 ppb	DOE 1992b						349ppb	310 μg/L			
480	STRONTIUM 89	14158-27-1	0.05 pCi/L (SW)	Dirkes 1994										0.07 pCi/L
481	STRONTIUM 90	10098-97-2	0.09 pCi/L (SW)	Dirkes et al. 1994	80000 pCi/L	36 pCi/L		130 pCi/L	28 pCi/L (d)		5.6 pCi/L	10 pCi/L	ND	0.16 pCi/L
482	STRONTIUM CHLORIDE	10476-85-4												
483	STRYCHNINE									ND				
484	STYRENE	100-42-5						ND		ND		ND	ND	
485	SULFATE	12808-79-8	90500 ppb	DOE 1992b	600000 μg/L					3000ppb	47900 μg/L	ND	ND	8600 μg/L
486	SULFIDE	18496-25-8								ND	3000 μg/L			
487	SULFUR OXIDES	20901-21-7												
488	SULFURIC ACID	7664-93-9												
489	SYM-TRINITROBENZENE									ND				
490	T(2,4,5)	93-76-5								ND		ND		
491	TCDD, 2,3,7,8-									ND				
492	TP,2,4,5- (SILVEX)									ND				
493	TECHNETIUM 99	14133-76-7	ND (SW)	Dirkes et al. 1994	700 pCi/L	46 pCi/L	2270 pCi/L	130 pCi/L			55 pCi/L	242 pCi/L	ND	ND
494	TETRACHLOROBENZENE, 1,2,4,5-									ND				
495	TETRACHLOROBENZENE, 1,2,3,4-									ND				
496	TETRACHLOROBENZENE, 1,2,3,5-									ND				
497	TETRACHLORODIBENZO-p-DIOXIN, 2,3,7,8-	1746-01-6												
498	TETRACHLORETHANE, 1,1,1,2-									ND				
499	TETRACHLORETHANE, 1,1,1-									ND				
500	TETRACHLORETHANE, 1,1,2-									ND				
501	TETRACHLOROETHANE, 1,1,2,2-	79-34-5						ND		ND		ND	ND	
502	TETRACHLOROETHYLENE	127-18-4	ND (SW)	Dirkes et al. 1993	3 μg/L			ND		ND	39 μg/L	ND	ND	ND
503	TETRACHLOROPHENOL, 2,3,4,6-									ND				
504	TETRAETHLPYROPHOSPHATE									ND				
505	TETRAHYDROFURAN	109-99-9								ND		ND	ND	ND
506	THALLIUM	7440-28-0			4 μg/L				ND	ND		ND	ND	
507	THALLIUM 208	14913-50-9												
508	THIOFANOX									ND				
509	THIOUREA	62-56-6								ND				
510	THIOUREA, 1-(O-CHLOROPHENYL)									ND				
511	THIURAM									ND				
512	THORIUM 228				3 pCi/L			ND				ND	ND	
513	THORIUM 229	15595-54-4						ND						
514	THORIUM 230	14268-63-7												
515	THORIUM 231													
516	THORIUM 232											44.49 pCi/L	ND	
517	THORIUM 234													
518	TIN	7440-31-5	ND (SW)	Dirkes et al. 1993					ND	ND		ND	ND	ND
519	TIN 113	13966-06-8												
520	TIN 126	15832-50-5												

Table A.1. (contd)

	Name of Analyte	CAS #	Background (a)	Background Reference	GROUNDWATER HEIS (DOE 1994c)	GROUNDWATER 100-XR-4 (DOE 1994f)	GROUNDWATER 100-HR-3 (DOE 1993d)	GROUNDWATER 100-BC-5 (DOE 1993a)	GROUNDWATER 100-N (Hartman & Lindsey 1993)	GROUNDWATER 1100 Area (Law 1990)	GROUNDWATER 300-FF-1 (DOE 1990b)	GROUNDWATER 300-FF-5 (DOE 1990a)	COLUMBIA RIVER 300-FF-5 (DOE 1990a)	COLUMBIA RIVER Richland Pumphouse (c)
521	TITANIUM	7440-32-6								ND				
522	TITANIUM CHLORIDE	10049-06-6												
523	TOLUENE	108-88-3						ND	ND	ND		2.9 µg/L	ND	4.7 µg/L
524	TOLUENEDIAMINE									ND				
525	TOXAPHENE	8001-35-2								ND		ND		
526	TP(2,4,5)SILVEX	93-72-1										ND		
527	TRIBROMOMETHANE	75-25-2												
528	TRIBUTYL PHOSPHATE	126-73-8												
529	TRIBUTYLPHOSPHORIC ACID													
530	TRICHLOROBENZENE, 1,2,3-									ND				
531	TRICHLOROBENZENE, 1,2,4-	120-82-1						ND		ND		ND		
532	TRICHLOROBENZENE, 1,3,5-									ND				
533	TRICHLOROETHANE, 1,1,1-	71-55-6						ND		ND		ND	ND	ND
534	TRICHLOROETHANE, 1,1,2-	79-00-5						ND				ND	ND	
535	TRICHLOROETHYLENE	79-01-6	ND (SW)	Dirkes et al. 1993	10 µg/L	19 µg/L		3 µg/L		ND	24.1 µg/L	16 µg/L	ND	ND
536	TRICHLOROMETHANETHIOL									ND				
537	TRICHLOROMONO FLUOROMETHANE									ND				
538	TRICHLOROPHENOL, 2,4,5-	95-95-4						ND		ND		ND		
539	TRICHLOROPHENOL, 2,4,6-	88-06-2						ND		ND		ND		
540	TRICHLOROPROPANE, 1,2,3-									ND				
541	TRIS(2,3-DIBROMOPROPYL) PHOSPH									ND				
542	TRITIUM (HYDROGEN 3)'	10028-17-8	40 pCi/L (SW)	Dirkes et al. 1994	70000 pCi/L	1900000 pCi/L	11000 pCi/L	24000 pCi/L	4430 pCi/L (d)	ND	6480 pCi/L	10000 pCi/g		175 pCi/L
543	TUNGSTEN	7440-33-7												
544	URANIUM	7440-61-1	3.43 pCi/L	DOE 1992b	500 µg/L						446 µg/L	210 µg/L		0.51 pCi/L
545	URANIUM (TOTAL ACTIVITY)											189 pCi/L	ND	
546	URANIUM 233	13968-55-3				3.3 pCi/L		1.2 pCi/L						
547	URANIUM 234	13966-29-5	0.24 pCi/L (SW)	Dirkes 1994	40 pCi/L		26.8 pCi/L	W/U233				120 pCi/L	18 pCi/L	0.25 pCi/L
548	URANIUM 235	15117-96-1	0.009 pCi/L (SW)	Dirkes 1994	6 pCi/L	0.29 pCi/L	2.43 pCi/L	ND				17 pCi/L	ND	0.010 pCi/L
549	URANIUM 236	13982-70-2										2.3 pCi/L (a)		
550	URANIUM 238	24678-82-8	0.19 pCi/L (SW)	Dirkes 1994	30 pCi/L	2.6 pCi/L	18.6 pCi/L	1.1 pCi/L				93 pCi/L	19 pCi/L	0.21 pCi/L
551	VANADIUM	7440-62-2	15 ppb	DOE 1992b	40 µg/L				32 ppb	18ppb	30 µg/L	19.3 µg/L	ND	ND
552	VANADIUM PENTOXIDE	13140-82-1												
553	VINYL ACETATE	108-05-4								ND		ND	ND	
554	VINYL CHLORIDE	75-01-4	ND (SW)	Dirkes et al. 1993				ND		ND		ND	ND	ND
555	WARFARIN									ND				
556	XYLENE	1330-20-7						ND	ND			ND	ND	4.0 µg/L
557	XYLENE, m-	108-38-3								ND				
558	XYLENE, o,p-													
559	YTTRIUM 90	10098-91-6												
560	ZINC	7440-66-6	<50 ppb (b)	DOE 1992b	500 µg/L		195 µg/L		6800 ppb	13ppb	260 µg/L	105 µg/L	ND	11 µg/L
561	ZINC 65	13982-39-3	ND (SW)	Dirkes 1994				ND				ND	ND	ND
562	ZINC AMALGAM													
563	ZINC CHLORIDE	1646-85-7												
564	ZINC COMPOUNDS	7646-85-7												
565	ZINC NITRATE	7779-88-6												
566	ZIRCONIUM	7440-67-7								ND				
567	ZIRCONIUM 93	15751-77-6												
568	ZIRCONIUM 95	13967-71-0												

(a) Provisional values estimated to be the background concentrations.
(b) Two analysis methods used: low-detection level and high-detection level. This applies to chloride, iron, manganese and zinc. The low levels are provided in the table.
(c) Dirkes 1993, Dirkes et al. 1993, Dirkes 1994.
(d) Detected in spring water.
(e) Jaquish 1989.

Table A.2. Radionuclide and Chemical Activity/Concentrations in Soil and Sediment

					SOIL								SEDIMENT	
	Name of Analyte	CAS #	Background(a)	Background Reference	100-KR-4 (DOE 1994f)	100-HR-1 (DOE 1993c)	100-BC-1 (DOE 1994d)	100-BC-5 (DOE 1993a)	100-N (b)	1100 Area (Law 1990)	300-FF-1 (DOE 1990b)	300-FF-5 (DOE 1990a)	300-FF-5 (DOE 1990a)	100 Areas (Weiss 1993)
1	ACENAPHTHENE	83-32-9	ND	DOE 1994a		210 µg/kg			ND					
2	ACENAPHTHYLENE	208-96-8	ND	DOE 1994a					ND					
3	ACETONE	67-64-1	ND	DOE 1994a					ND			ND	ND	
4	ACETOPHENONE	98-86-2	ND	DOE 1990b							ND			
5	ACETYLAMINOFLUORENE, 2-	53-96-3	ND	DOE 1990b							ND			
6	ACRYLAMIDE	79-06-1	ND	DOE 1990b										
7	ACROLEIN	107-02-8	ND	DOE 1990b							ND			
8	ACRYLONITRILE	107-13-1	ND	DOE 1990b							ND			
9	ACTINIUM 227	14952-40-0												
10	ALDRIN	309-00-2	ND	DOE 1994a										
11	ALLYL ALCOHOL	107-18-6	ND	DOE 1990b										
12	ALPHA, ALPHA-DIMETHYLPHENETHYLAMINE	99-98-9	ND	DOE 1990b							ND			
13	ALPHA-BHC	319-84-6	ND	DOE 1994a										
14	ALPHA-CHLORDANE	5103-71-9	ND	DOE 1994a										
15	ALUMINUM	7429-90-5	13621 mg/kg	DOE 1994a	7700 mg/kg	9070 mg/kg	12500 mg/kg				26,700 mg/kg	8760 mg/kg	6750 mg/kg	9,350 mg/kg
16	ALUMINUM NITRATE	13473-90-0												
17	ALUMINUM SULFATE	10043-01-3												
18	AMERICIUM 241	7440-35-9				0.72 pCi/g	34 pCi/g							ND
19	AMERICIUM 242M	13981-54-9												
20	AMERICIUM 243	14993-75-0												
21	AMINOBYPHENYL, 4-	92-67-1	ND	DOE 1990b							ND			
22	AMINOMETHYL-3 ISOAZOLOL, 5-	2763-96-4	ND	DOE 1990b							ND			
23	AMITROLE	61-82-5	ND	DOE 1990b							ND			
24	AMMONIA	7664-41-7	16.0 mg/kg	DOE 1994a								12.8 mg/kg	12 mg/kg	
25	AMMONIUM	14798-03-9	ND	DOE 1990b										
26	AMMONIUM ACETATE	631-61-8												
27	AMMONIUM CARBONATE	506-87-6												
28	AMMONIUM CHLORIDE	12125-02-9												
29	AMMONIUM FLUORIDE	12125-10-8												
30	AMMONIUM NITRATE	6484-52-2												
31	AMMONIUM OXALATE	1113-38-8												
32	AMMONIUM SILICOFLUORIDE	1309-32-6												
33	AMMONIUM SULFATE	7783-20-2												
34	AMMONIUM SULFITE	10196-04-0												
35	AMMONIUM THIOSULFATE	7783-18-8												
36	ANILINE	62-53-3	ND	DOE 1990b							ND			
37	ANTHRACENE	120-12-7	ND	DOE 1994a		430 µg/kg			ND					
38	ANTIMONY	7440-36-0	ND	DOE 1994a			ND				ND	ND	ND	ND
39	ANTIMONY (III) NITRATE	20328-96-5												
40	ANTIMONY 124	7440-36-0												1.2 pCi/kg
41	ANTIMONY 125	14234-35-6											ND	
42	ANTIMONY CHLORIDE	10025-9-19												
43	ARAMITE	140-57-8	ND	DOE 1990b							ND			
44	AROCHLOR-1221	11104-28-2	ND	DOE 1994a							ND	ND		
45	AROCHLOR-1232	11141-16-5	ND	DOE 1994a							ND	ND		
46	AROCHLOR-1260	11096-82-5	ND	DOE 1994a							ND	ND		
47	AROCLOR 1016 (PCB)	12674-11-2	ND	DOE 1994a							ND	ND		
48	AROCLOR 1242 (PCB)	53469-21-9	ND	DOE 1994a							ND	ND		
49	AROCLOR 1248 (PCB)	12672-29-6	ND	DOE 1994a							9.9 mg/kg	ND		
50	AROCLOR 1254 (PCB)	11091-69-1	ND	DOE 1994a							ND	ND		
51	ARSENIC	7440-38-2	7.6 mg/kg	DOE 1994a		47 mg/kg	2.2 mg/kg				ND	9.3 mg/kg	7.5 mg/kg	
52	ARSENIC TRIOXIDE	1327-53-3												
53	ASBESTOS	332-21-4												
54	AURAMINE	492-80-8	ND	DOE 1990b							ND			
55	BARIUM	7440-39-3	155.9 mg/kg	DOE 1994a	85 mg/kg	672 mg/kg *	484 mg/kg				133 mg/kg	260 mg/kg	67.3 mg/kg	120 mg/kg
56	BARIUM 133	13981-41-4												
57	BARIUM 140	7440-39-3					ND					ND		
58	BARIUM NITRATE	10022-31-8												

9513332.1822

Table A.2. (contd)

	Name of Analyte	CAS #	Background(a)	Background Reference	SOIL 100-KR-4 (DOE 1994f)	100-HR-1 (DOE 1993c)	100-BC-1 (DOE 1994d)	100-BC-5 (DOE 1993a)	100-N (b)	1100 Area (Law 1990)	300-FF-1 (DOE 1990b)	300-FF-5 (DOE 1990a)	SEDIMENT 300-FF-5 (DOE 1990a)	100 Areas (Weiss 1993)
59	BENZENE	71-43-2	ND	DOE 1994a					4.5 mg/kg		ND	ND	ND	
60	BENZENETHIOL	108-98-5	ND	DOE 1990b							ND			
61	BENZIDINE	92-87-5	ND	DOE 1990b							ND			
62	BENZO[a]ANTHRACENE	56-55-3	ND	DOE 1994a		940 µg/kg			ND		ND			
63	BENZO[a]PYRENE	50-32-8	ND	DOE 1994a		810 µg/kg *			ND		ND			
64	BENZO[b]FLUORANTHENE	205-99-2	ND	DOE 1994a		890 µg/kg			ND		ND			
65	BENZO(G,H,I)PERYLENE	191-24-2	ND	DOE 1994a		410 µg/kg			ND					
66	BENZO[j]FLUORANTHENE	94-58-6	ND	DOE 1990b							ND			
67	BENZO[K]FLUORANTHENE	207-08-9	ND	DOE 1994a		760 µg/kg			ND					
68	BENZOIC ACID	65-85-0	ND	DOE 1994a			1700 µg/kg							
69	BENZOQUINONE, P-	106-51-4	ND	DOE 1990b							ND			
70	BENZYL ALCOHOL	100-51-6	ND	DOE 1994a					ND					
71	BENZYL CHLORIDE	100-44-7	ND	DOE 1990b							ND			
72	BERYLLIUM	7440-41-7	1.6 mg/kg	DOE 1994a		4.7 mg/kg	0.49 mg/kg				8 mg/kg	.93 mg/kg	ND	1.1 mg/kg
73	BERYLLIUM 7	7440-41-7					ND					ND		
74	BETA-BHC	319-85-7	ND	DOE 1994a										
75	BIS(2-CHLOROETHOXY)METHANE	111-91-1	ND	DOE 1994a					ND		ND			
76	BIS(2-CHLOROETHYL)ETHER	111-44-4	ND	DOE 1994a					ND		ND			
77	BIS(2-CHLOROISOPROPYL)ETHER	39638-32-9	ND	DOE 1994a					ND		ND			
78	BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	ND	DOE 1994a		68 mg/kg			ND		ND			
79	BIS(CHLOROMETHYL) ETHER	542-88-1	ND	DOE 1990b							ND			
80	BISMUTH	7440-69-9												
81	BISMUTH 212	14913-49-6												
82	BISMUTH 214	14733-03-0												
83	BORON	7440-42-8												
84	BROMOACETONE	598-31-2	ND	DOE 1990b							ND			
85	BROMODICHLOROMETHANE	75-27-4	ND	DOE 1994a					ND			ND	ND	
86	BROMOFORM	75-25-2	ND	DOE 1994a					ND		ND	ND	ND	
87	BROMOMETHANE	74-83-9	ND	DOE 1994a					ND			ND	ND	
88	BROMOPHENYL-PHENYLETHER, 4-	101-55-3	ND	DOE 1994a					ND		ND			
89	BUTANOL, 1-	71-36-3												
90	BUTANONE	78-93-3							ND					
91	BUTANONE, 2-	78-93-3	ND	DOE 1994a								ND	ND	
92	BUTYL BENZYL PHTHALATE	85-68-7	ND	DOE 1994a					ND		ND			
93	BUTYL PHTHALATE, DI-N-	84-74-2	ND	DOE 1990b										
94	CADMIUM	7440-43-9	ND	DOE 1994a			1.8 mg/kg				1 mg/kg	ND	ND	2.70 mg/kg
95	CADMIUM 109	14109-32-1												
96	CADMIUM NITRATE	10325-97-7												
97	CALCIUM	7440-70-2	21012 mg/kg	DOE 1994a	7730 mg/kg	8620 mg/kg	14500 mg/kg				33,200 mg/kg	40800 mg/kg	4460 mg/kg	9000 mg/kg
98	CALCIUM 41	14092-95-6												
99	CALCIUM BICARBONATE	1317-65-3												
100	CARBAZOLE	86-74-8												
101	CARBAZOLE, 9H-	86-74-8												
102	CARBON 14	14762-75-5				34 pCi/g	2.48 pCi/g							
103	CARBON DISULFIDE	75-15-0	ND	DOE 1994a					ND.		ND	ND	ND	
104	CARBON TETRACHLORIDE	56-23-5	ND	DOE 1994a					ND		ND	ND	ND	
105	CARBOPHENOTHION		ND	DOE 1990b										
106	CERIUM	7440-45-1												
107	CERIUM 141	13967-74-3					ND					ND		ND
108	CERIUM 144	14762-78-8					ND					ND		
109	CESIUM 134	13967-70-9				0.04 pCi/g	ND					ND	ND	0.29 pCi/g
110	CESIUM 135	15726-30-4												
111	CESIUM 137	10045-97-3				2900 pCi/g	800 pCi/g					0.23 pCi/g	.23 pCi/G	6.0 pCi/g
112	CHLORAL	75-87-6	ND	DOE 1990b										
113	CHLORDANE	57-74-9	ND	DOE 1990b								4.5 mg/kg	ND	
114	CHLORIDE	16887-00-6									1.1 mg/kg			
115	CHLORINE	7782-50-5	331.3 mg/kg	DOE 1994a										
116	CHLORNAPHAZINE	494-03-1	ND	DOE 1990b										

Table A.2. (contd)

					SOIL								SEDIMENT	
	Name of Analyte	CAS #	Background(a)	Background Reference	100-KR-4 (DOE 1994f)	100-HR-1 (DOE 1993c)	100-BC-1 (DOE 1994d)	100-BC-5 (DOE 1993a)	100-N (b)	1100 Area (Law 1990)	300-FF-1 (DOE 1990b)	300-FF-5 (DOE 1990a)	300-FF-5 (DOE 1990a)	100 Areas (Weiss 1993)
117	CHLORO-2,3-EPOXYPROPANE, 1-		ND	DOE 1990b							ND			
118	CHLORO-M-CRESOL, P-	59-50-7	ND	DOE 1990b							ND			
119	CHLOROACETALDEHYDE	107-20-0	ND	DOE 1990b										
120	CHLOROALKYL ETHERS		ND	DOE 1990b							ND			
121	CHLOROANILINE, 4-	106-47-8	ND	DOE 1994a					ND					
122	CHLOROBENZENE	108-90-7	ND	DOE 1994a					ND		ND	ND	ND	
123	CHLOROBENZILATE	510-15-6	ND	DOE 1990b										
124	CHLORODIBROMOMETHANE	124-48-1		DOE 1994a										
125	CHLOROETHANE	75-00-3	ND	DOE 1994a					ND			ND	ND	
126	CHLOROETHOXY ETHENE, 2-	110-75-8										ND	ND	
127	CHLOROETHYLVINYL ETHER, 2-	110-75-8	ND	DOE 1990b							ND			
128	CHLOROFORM	67-66-3	ND	DOE 1994a			ND		ND		ND	ND	ND	
129	CHLOROMETHANE	74-87-3	ND	DOE 1994a					ND			ND	ND	
130	CHLOROMETHYLMETHYL ETHER	107-30-2	ND	DOE 1990b							ND			
131	CHLOROMETHYLPHENOL, 4-3-	35421-08-0							ND					
132	CHLORONAPHTHALENE, 2-	91-58-7	ND	DOE 1994a					ND		ND			
133	CHLOROPHENOL, 2-	95-57-8	ND	DOE 1994a					ND		ND			
134	CHLOROPHENYL-PHENYL ETHER, 4-	7005-72-3	ND	DOE 1994a					ND					
135	CHLOROPROPIONITRILE, 3-	542-76-7	ND	DOE 1990b										
136	CHROMIC ACID	7738-94-5												
137	CHROMIUM	7440-47-3	24.1 mg/kg	DOE 1994a		114 mg/kg	20.2 mg/kg				259 mg/kg	28.9 mg/kg	13.8 mg/kg	122 mg/kg
138	CHROMIUM (IV)	15723-28-1												
139	CHROMIUM (VI)	18540-29-9												
140	CHROMIUM 51	14392-02-0					ND					ND	ND	ND
141	CHROMIUM NITRATE	13548-38-4												
142	CHROMIUM SULFATE	10101-53-8												
143	CHRYSENE	218-01-9	ND	DOE 1994a		920 µg/kg			ND		ND			
144	CITRIS RED #2	6358-53-8	ND	DOE 1990b										
145	COBALT	7440-48-4	17.6 mg/kg	DOE 1994a	14.2 mg/kg	9.9 mg/kg	16.4 mg/kg					34.1 mg/kg	ND	11.5 mg/kg
146	COBALT 58	13981-38-9					ND					ND		
147	COBALT 60	10198-40-0	ND	DOE 1990b		18000 pCi/g	310 pCi/g					0.78 pCi/g	0.78 pCi/g	4.9 pCi/g
148	COPPER	7440-50-8	25.9 mg/kg	DOE 1994a	9 mg/kg	140000 mg/k	27.8 mg/kg				2850 mg/kg	ND	16.1 mg/kg	40 mg/kg
149	COPPER NITRATE	3251-23-8												
150	COPPER SULFATE	7558-98-7												
151	CRESOLS	1319-77-3	ND	DOE 1990b							ND			
152	CROTONALDEHYDE	123-73-9	ND	DOE 1990b							ND			
153	CURIUM 242	15510-73-3												
154	CURIUM 244	13981-15-2												
155	CURIUM 245	15621-76-8												
156	CYANIDE	57-12-5	ND	DOE 1990b			1.05 mg/kg					ND	ND	
157	CYANOGEN	460-19-5	ND	DOE 1990b										
158	CYANOGEN CHLORIDE	506-77-4	ND	DOE 1990b										
159	CYANOGEN BROMIDE	506-68-3												
160	CYCLOHEXYL-4,6-DINITROPHENOL, 2-	131-89-5	ND	DOE 1990b							ND			
161	D(2,4)	94-75-7	ND	DOE 1990b										
162	DDD, 4,4'-	72-54-8	ND	DOE 1994a										
163	DDE, 4,4'-	72-55-9	ND	DOE 1994a										
164	DDT, 4,4'-	50-29-3	ND	DOE 1994a										
165	DELTA-BHC	319-86-8	ND	DOE 1994a										
166	DI-N-BUTYLPHTHALATE	84-74-2	ND	DOE 1994a					ND		ND			
167	DI-N-OCTYLPHTHALATE	117-84-0	ND	DOE 1994a					ND		ND			
168	DI-N-PROPYLNITROSAMINE	621-64-7	ND	DOE 1990b							ND			
169	DIBENZ(A,G)ANTHRACENE	53-70-3												
170	DIBENZ(A,H)ACRIDINE	226-36-8	ND	DOE 1990b							ND			
171	DIBENZ(A,H)ANTHRACENE	53-70-3	ND	DOE 1994a					ND		ND			
172	DIBENZ(A,J)ACRIDINE	224-42-0	ND	DOE 1990b							ND			
173	DIBENZO(A,E)PYRENE	192-65-4	ND	DOE 1990b							ND			
174	DIBENZO(A,H)PYRENE	189-64-0	ND	DOE 1990b							ND			

Table A.2. (contd)

					SOIL								SEDIMENT	
	Name of Analyte	CAS #	Background(a)	Background Reference	100-KR-4 (DOE 1994f)	100-HR-1 (DOE 1993c)	100-BC-1 (DOE 1994d)	100-BC-5 (DOE 1993a)	100-N (b)	1100 Area (Law 1990)	300-FF-1 (DOE 1990b)	300-FF-5 (DOE 1990a)	300-FF-5 (DOE 1990a)	100 Areas (Weiss 1993)
175	DIBENZO(A,I)PYRENE	189-55-9	ND	DOE 1990b							ND			
176	DIBENZO(C,G)CARBAZOLE, 7H-		ND	DOE 1990b							ND			
177	DIBENZOFURAN	132-64-9	ND	DOE 1994a		130 µg/kg								
178	DIBROMOMETHANE	74-95-3	ND	DOE 1990b							ND			
179	DIBROMO-3-CHLOROPROPANE, 1,2-	96-12-8	ND	DOE 1990b							ND			
180	DIBROMOCHLOROMETHANE	124-48-1	ND	DOE 1994a					ND			ND	ND	
181	DIBROMOETHANE, 1,2-	106-93-4	ND	DOE 1990b							ND			
182	DICHLORO-2-BUTANE, 1,4-	618-21-7	ND	DOE 1990b							ND			
183	DICHLOROBENZENE, 1,2-	95-50-1	ND	DOE 1994a					ND		ND			
184	DICHLOROBENZENE, 1,3-	541-73-1	ND	DOE 1994a					ND		ND			
185	DICHLOROBENZENE, 1,4-	106-46-7	ND	DOE 1994a					ND		ND			
186	DICHLOROBENZIDINE, 3,3'	91-94-1	ND	DOE 1994a					ND		ND			
187	DICHLORODIFLUOROMETHANE	75-71-8	ND	DOE 1990b							ND			
188	DICHLOROETHANE, 1,1-	75-34-3	ND	DOE 1994a					ND		ND	ND	ND	
189	DICHLOROETHANE, 1,2-	107-06-2	ND	DOE 1994a					ND		ND	ND	ND	
190	DICHLOROETHENE	25323-30-2	ND	DOE 1990b							ND			
191	DICHLOROETHYLENE, 1,1-	75-35-4	ND	DOE 1994a					ND		ND	ND	ND	
192	DICHLOROETHYLENE, 1,2-	540-59-0	ND	DOE 1994a								ND	ND	
193	DICHLOROETHYLENE, 1,2-cis-	156-59-2												
194	DICHLOROETHYLENE, 1,2-trans-	156-60-5												
195	DICHLOROMETHYLBENZENE		ND	DOE 1990b							ND			
196	DICHLOROPHENOL, 2,4-	120-83-2	ND	DOE 1994a					ND		ND			
197	DICHLOROPHENOL, 2,6-	87-65-0									ND			
198	DICHLOROPHENOXYACETIC ACID, 2,4-	94-75-7												
199	DICHLOROPROPANE, 1,2-	78-87-5	ND	DOE 1994a					ND		ND	ND	ND	
200	DICHLOROPROPANE, 1,3-	142-28-9	ND	DOE 1990b							ND			
201	DICHLOROPROPANOL	26545-73-3	ND	DOE 1990b										
202	DICHLOROPROPENE, 1,3-cis-	10061-02-6	ND	DOE 1994a					ND			ND	ND	
203	DICHLOROPROPENE, 1,3-trans-	10061-01-5	ND	DOE 1994a					ND			ND	ND	
204	DIELDRIN	60-57-1	ND	DOE 1994a										
205	DIESEL FUEL								2800 mg/kg					
206	DIETHYLARSINE	692-42-2	ND	DOE 1990b							ND			
207	DIETHYLHYDRAZINE, N,N	1615-80-1	ND	DOE 1990b							ND			
208	DIETHYLPHTHALATE	84-66-2	ND	DOE 1990b					ND		ND			
209	DIMETHOXYBENZIDINE, 3,3'-	119-90-4	ND	DOE 1994a							ND			
210	DIETHYLSTILBESTEROL	56-53-1	ND	DOE 1990b										
211	DIHYDROSAFROLE	94-58-6	ND	DOE 1990b							ND			
212	DIMETHOATE	60-51-5	ND	DOE 1990b										
213	DIMETHYLBENZIDINE, 3,3'	119-93-7	ND	DOE 1990b							ND			
214	DIMETHYLHYDRAZINE, 1,1-	57-14-7												
215	DIMETHYLHYDRAZINE, 1,2-		ND	DOE 1990b										
216	DIMETHYLPHENOL, 2,4-	105-67-9	ND	DOE 1994a					ND		ND			
217	DIMETHYLPHTHALATE	131-11-3	ND	DOE 1994a					ND		ND			
218	DIMENTYLAMINOAZOBENZENE, P-	60-11-7	ND	DOE 1990b							ND			
219	DIMENTYLBENZ(A)ANTHRACENE, 7,12-		ND	DOE 1990b							ND			
220	DINITRO-2-METHYLPHENOL, 4,6-	534-42-1	ND	DOE 1994a					ND					
221	DINITRO-O-CRESOL, 4,6- and salts	534-52-1	ND	DOE 1990b							ND			
222	DINITROBENZENE	25154-54-5	ND	DOE 1990b							ND			
223	DINITROPHENOL, 2,4-	51-28-5	ND	DOE 1994a					ND		ND			
224	DINITROPHENOL, 2-SEC-BUTYL-4,6-		ND	DOE 1990b							ND			
225	DINITROTOLUENE, 2,4-	121-14-2	ND	DOE 1994a					ND					
226	DINITROTOLUENE, 2,6-	606-20-2	ND	DOE 1994a					ND		ND			
227	DIOXANE		ND	DOE 1990b							ND			
228	DIOXIN		ND	DOE 1990b										
229	DIPHENYLAMINE	122-39-4	ND	DOE 1990b							ND			
230	DIPHENYLHYDRAZINE, 1,2-	122-66-7	ND	DOE 1990b							ND			
231	DISULFOTON	298-04-4	ND	DOE 1990b										
232	ENDOSULFAN I	959-98-8	ND	DOE 1994a										

Table A.2. (contd)

					SOIL								SEDIMENT	
	Name of Analyte	CAS #	Background(s)	Background Reference	100-KR-4 (DOE 1994f)	100-HR-1 (DOE 1993c)	100-BC-1 (DOE 1994d)	100-BC-5 (DOE 1993a)	100-N (b)	1100 Area (Law 1990)	300-FF-1 (DOE 1990b)	300-FF-5 (DOE 1990a)	300-FF-5 (DOE 1990a)	100 Areas (Weiss 1993)
233	ENDOSULFAN II	33213-65-9	ND	DOE 1994a										
234	ENDOSULFAN SULFATE	1031-07-8	ND	DOE 1994a										
235	ENDRIN	72-20-8	ND	DOE 1994a										
236	ENDRIN ALDEHYDE	7421-93-4	ND	DOE 1994a			3.3 µg/kg							
237	ENDRIN KETONE	53494-70-5	ND	DOE 1994a										
238	ETHYL CARBAMATE	51-79-6	ND	DOE 1990b										
239	ETHYL CYANIDE	107-12-0	ND	DOE 1990b										
240	ETHYL METHANESULFONATE	62-50-0	ND	DOE 1990b							ND			
241	ETHYLBENZENE	100-41-4	ND	DOE 1990b					32 mg/kg					
242	ETHYLENE GLYCOL	107-21-1	ND	DOE 1990b										
243	ETHYLENE OXIDE	100-41-4	ND	DOE 1994a								ND	ND	
244	ETHYLENEIMINE	151-56-4	ND	DOE 1990b							ND			
245	ETHYLENE THIOUREA	96-45-7	ND	DOE 1990b										
246	ETHYL METHACRYLATE	97-63-2	ND	DOE 1990b							ND			
247	EUROPIUM 152	14683-23-9				59000 pCi/g	1400 pCi/g					0.17 pCi/g	.17 pCi/G	2.41 pCi/g
248	EUROPIUM 154	15585-10-1				20000 pCi/g	410 pCi/g						ND	0.24 pCi/g
249	EUROPIUM 155	14391-16-3				6200 pCi/g	41 pCi/g							0.32 pCi/g
250	FERRIC NITRATE	10421-48-4												
251	FERRIC SULFATE	10028-22-5												
252	FERROCYANIDE	13408-63-4												
253	FERROUS AMMONIUM SULFATE	7783-85-9												
254	FERROUS SULFATE	7720-78-7												
255	FLUORANTHENE	206-44-0	ND	DOE 1994a		1800 pCi/g			ND		ND			
256	FLUORENE	86-73-7	ND	DOE 1994a		190 pCi/g			ND					
257	FLUORIDE	7782-41-4									2.0 mg/kg	4.7 mg/kg	ND	
258	FLUORINE	7782-41-4	5.3 mg/kg	DOE 1994a										
259	FLUOROACETIC ACID	144-49-0	ND	DOE 1990b										
260	FLUOROTRICHLOROMETHANE	75-69-4												
261	FORMALIN		ND	DOE 1990b							ND			
262	FUEL OIL #2	68476-34-6												
263	GAMMA-BHC(LINDANE)	58-89-9	ND	DOE 1994a										
264	GAMMA-CHLORDANE	5103-74-2	ND	DOE 1994a										
265	GASOLINE								ND					
266	GLYCIDYLALDEHYDE	765-34-4	ND	DOE 1990b										
267	HAPHTHYLAMINE, 2-		ND	DOE 1990b										
268	HEPTACHLOR	76-44-8	ND	DOE 1994a										
269	HEPTACHLOR EPOXIDE	1024-57-3												
270	HEPTACHLOR EPOXIDE (ENDO)	1024-57-3	ND	DOE 1994a										
271	HEPTACHLOR EPOXIDE (EXO)	1024-57-3	ND	DOE 1994a										
272	HEXACHLOROBENZENE	118-74-1	ND	DOE 1994a					ND		ND			
273	HEXACHLOROBUTADIENE	87-68-3	ND	DOE 1994a					ND		ND			
274	HEXACHLOROCYCLOPENTADIENE	77-47-4	ND	DOE 1994a					ND					
275	HEXACHLOROETHANE	67-72-1	ND	DOE 1994a					ND		ND			
276	HEXACHLOROPHENE	70-30-4	ND	DOE 1990b							ND			
277	HEXACHLOROPROPENE	1888-71-7	ND	DOE 1990b							ND			
278	HEXANONE, 2-	591-78-6	ND	DOE 1994a					ND			ND	ND	
279	HEXONE	108-10-1									ND			
280	HEXYL METHANOATE	629-33-4												
281	HYDRAZINE	302-01-2	ND	DOE 1990b										
282	HYDROCARBONS													
283	HYDROCHLORIC ACID	7647-01-0												
284	HYDROCYANIC ACID	74-90-8												
285	HYDROFLUORIC ACID	7664-39-3												
286	HYDROGEN SULFIDE	7783-06-4	ND	DOE 1990b							ND			
287	INDENO(1,2,3-CD)PYRENE	193-39-5	ND	DOE 1994a		520 µg/kg *			ND		ND			
288	IODINE 129	15046-84-1											ND	
289	IODINE 131	10043-66-0					ND					ND		
290	IODOMETHANE		ND	DOE 1990b							ND			

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Table A.2. (contd)

					SOIL								SEDIMENT	
	Name of Analyte	CAS #	Background(a)	Background Reference	100-KR-4 (DOE 1994f)	100-HR-1 (DOE 1993c)	100-BC-1 (DOE 1994d)	100-BC-5 (DOE 1993a)	100-N (b)	1100 Area (Law 1990)	300-FF-1 (DOE 1990b)	300-FF-5 (DOE 1990a)	300-FF-5 (DOE 1990a)	100 Areas (Weiss 1993)
291	IRON	7439-89-6	35746 mg/kg	DOE 1994a	25500 mg/kg	19000 mg/kg	44600 mg/kg				33,500 mg/kg	19500 mg/kg	17000 mg/kg	171000 mg/k
292	IRON 59						ND					ND	ND	ND
293	ISOBUTYL ALCOHOL	78-83-1	ND	DOE 1990b										
294	ISOPHORONE	78-59-1	ND	DOE 1994a					ND					
295	ISOSAFROLE	120-58-1	ND	DOE 1990b							ND			
296	KEROSENE	8008-20-6	ND	DOE 1990b					3085 mg/kg		ND			
297	KRYPTON 85													
298	LANTHANUM	7439-91-0												
299	LEAD	7439-92-1	12.6 mg/kg	DOE 1994a	7.6 µg/L	540 mg/kg	4.8 mg/kg				ND	15.6 mg/kg	17.4 mg/kg	73 mg/kg
300	LEAD 210	14255-04-0												
301	LEAD 212	15092-94-1												
302	LEAD NITRATE	10099-74-8												
303	LITHIUM	7439-93-2	35 mg/kg	DOE 1994a										
304	LITHIUM CHLORIDE	7447-41-8												
305	MAGNESIUM	7439-95-4	8169 mg/kg	DOE 1994a	5030 mg/kg	4720 mg/kg	6390 mg/kg				11,600 mg/kg	8540 mg/kg	4020 mg/kg	7600 mg/kg
306	MALEIC HYDRAZIDE	123-33-1	ND	DOE 1990b							ND			
307	MALONONITRILE	109-77-3	ND	DOE 1990b							ND			
308	MANGANESE	7439-96-5	548 mg/kg	DOE 1994a	330 mg/kg	3050 mg/kg	839 mg/kg				396 mg/kg	403.2 mg/kg	327 mg/kg	578 mg/kg
309	MANGANESE 54	13966-31-9					ND					ND		0.057 pCi/g
310	MELPHALAN	148-82-3	ND	DOE 1990b							ND			
311	MERCURIC NITRATE	10045-95-0												
312	MERCURIC THIOCYANATE	592-85-8												
313	MERCURY	7439-97-6	0.61 mg/kg	DOE 1994a	1.4 mg/kg	1.1 mg/kg	4.3 mg/kg				2.77 mg/kg	.54 mg/kg	ND	ND
314	METHACRYLONITRILE	126-98-7	ND	DOE 1990b							ND			
315	METHANAL	50-00-0												
316	METHANETHIOL	74-93-1	ND	DOE 1990b							ND			
317	METHANOL	67-56-1												
318	METHAPYRILENE	91-80-5	ND	DOE 1990b							ND			
319	METHOLONYL		ND	DOE 1990b							ND			
320	METHOXYCHLOR	72-43-5	ND	DOE 1994a										
321	METHYL BROMIDE	74-83-9	ND	DOE 1990b							ND			
322	METHYL CHLORIDE	74-87-3	ND	DOE 1990b							ND			
323	METHYL ETHYL KETONE	78-93-3	ND	DOE 1990b							ND			
324	METHYL METHACRYLATE	80-62-6	ND	DOE 1990b							ND			
325	METHYL METHANESULFONATE	66-27-3	ND	DOE 1990b							ND			
326	METHYL PARATHION	298-00-0	ND	DOE 1990b										
327	METHYL-2-(METHYLIO)PROPIONALDEHYDE, 2-		ND	DOE 1990b							ND			
328	METHYL-2-PENTANONE, 4-	108-10-1	ND	DOE 1994a					ND			22 mg/kg	ND	
329	METHYLAZIRIDINE, 2-	75-55-8	ND	DOE 1990b							ND			
330	METHYLCHOLANTHRENE, 3-	56-49-5	ND	DOE 1990b							ND			
331	METHYLENE bis(3,4,6-TRICHLOROPHENOL)	70-30-4												
332	METHYLENE CHLORIDE	75-09-2	ND	DOE 1994a	120 µg/kg		ND		ND		ND	ND	ND	
333	METHYLENE BIS(2-CHLOROANILINE), 4-4'-	101-14-4	ND	DOE 1990b							ND			
334	METHYLHYDRAZINE		ND	DOE 1990b										
335	METHYLLACTONITRILE, 2-	75-86-5	ND	DOE 1990b							ND			
336	METHYLNAPHTHALENE, 2-	91-57-6	ND	DOE 1994a		42 µg/kg			ND					
337	METHYLPHENOL, 2-	95-48-7	ND	DOE 1994a					ND					
338	METHYLPHENOL, 4-	106-44-5	ND	DOE 1994a					ND					
339	METHYLPHENOL, 4-CHLORO-3-	59-50-7	ND	DOE 1994a										
340	METHYLTHIOURACIL	56-04-2	ND	DOE 1990b							ND			
341	METHOXYCHLOR	72-43-5	ND	DOE 1990b										
342	MOLYBDENUM	7439-98-7	ND	DOE 1994a										
343	PROPYLAMINE, N-	107-10-8	ND	DOE 1990b										
344	NAPHTHALENE	91-20-7	ND	DOE 1994a					ND		ND			
345	NAPHTHOQUINONE, 1,4-	130-15-4	ND	DOE 1990b							ND			
346	NAPHTHYLAMINE, 1-	91-59-8	ND	DOE 1990b							ND			
347	NAPHTHYLAMINE, 2-		ND	DOE 1990b										
348	NEPTUNIUM 237	13994-20-2												0.606 pCi/g

Table A.2. (contd)

	Name of Analyte	CAS #	Background(a)	Background Reference	SOIL 100-KR-4 (DOE 1994f)	100-HR-1 (DOE 1993c)	100-BC-1 (DOE 1994d)	100-BC-5 (DOE 1993a)	100-N (b)	1100 Area (Law 1990)	300-FF-1 (DOE 1990b)	300-FF-5 (DOE 1990a)	SEDIMENT 300-FF-5 (DOE 1990a)	100 Areas (Weiss 1993)
349	NEPTUNIUM 239	13968-59-7												
350	NICKEL	7440-02-0	22.2 mg/kg	DOE 1994a	18 mg/kg	132 mg/kg	24.3 mg/kg				221 mg/kg	17.2 mg/kg	13.3 mg/kg	19.7 mg/kg
351	NICKEL 59	14336-70-0												
352	NICKEL 63	13981-37-8				20000 pCi/g								
353	NICKEL FERROCYANIDE	14874-78-3												
354	NICKEL NITRATE	13138-45-9												
355	NICKEL SULFATE	7786-81-4												
356	NICOTINIC ACID		ND	DOE 1990b							ND			
357	NIOBIUM 95	13967-76-5												
358	NITRATE	14797-55-8			4.3 mg/kg		5.9 mg/kg				30.4 mg/kg	12.7 mg/kg	ND	
359	NITRIC ACID	7697-37-2												
360	NITRITE	14797-65-0										ND	ND	
361	NITRO-O-TOLUIDINE, 5-	99-55-8	ND	DOE 1990b										
362	NITROANILINE, 2-	88-74-4	ND	DOE 1994a					ND					
363	NITROANILINE, 3-	99-09-2	ND	DOE 1994a					ND					
364	NITROANILINE, 4-	100-01-6	ND	DOE 1994a					ND					
365	NITROBENZENE	98-95-3	ND	DOE 1994a					ND		ND			
366	NITROGEN OXIDE	10024-97-2												
367	NITROPHENOL, 2-	88-75-5	ND	DOE 1994a					ND					
368	NITROPHENOL, 4-	100-02-7	ND	DOE 1994a					ND		ND			
369	NITROSO-DI-N-PROPYLAMINE, N-	621-64-7	ND	DOE 1994a					ND					
370	NITROSO-N-METHYLURETHANE, N-	615-53-2	ND	DOE 1990b							ND			
371	NITROSODI-N-BUTYLAMINE, N-	924-16-3	ND	DOE 1990b							ND			
372	NITROSODIETHANOLAMINE, N-	1116-54-7	ND	DOE 1990b							ND			
373	NITROSODIETHYLAMINE, N-	55-18-5	ND	DOE 1990b							ND			
374	NITROSODIMETHYLAMINE, N-	62-75-9	ND	DOE 1990b							ND			
375	NITROSODIPHENYLAMINE, N-	86-30-6	ND	DOE 1994a					ND					
376	NITROSOMETHYLETHYLAMINE, N-	10595-95-6	ND	DOE 1990b							ND			
377	NITROSOMETHYLVINYLAMINE, N-	4549-40-0	ND	DOE 1990b							ND			
378	NITROSOMORPHOLINE, N-	59-89-2	ND	DOE 1990b							ND			
379	NITROSONORNICOTINE, N-	16543-55-8	ND	DOE 1990b							ND			
380	NITROSOPIPERIDINE, N-	100-75-4	ND	DOE 1990b							ND			
381	NITROSOPYRROLIDINE	930-55-2	ND	DOE 1990b							ND			
382	ORTHO-PHOSPHATE													
383	OSMIUM		ND	DOE 1990b							ND			
384	OXYBIS(1-CHLOROPROPANE), 2,2'-													
385	PALLADIUM	7440-05-3												
386	PARALDEHYDE	123-63-7	ND	DOE 1990b										
387	PARATHION	56-38-2	ND	DOE 1990b										
388	PENTACHLOROBENZENE	608-93-5	ND	DOE 1990b							ND			
389	PENTACHLOROETHANE	76-01-7	ND	DOE 1990b							ND			
390	PENTACHLORONITROBENZENE	82-68-8	ND	DOE 1990b							ND			
391	PENTACHLOROPHENOL	87-86-5	ND	DOE 1994a					ND		ND			
392	PERCHLORATE		ND	DOE 1990b										
393	PERCHLOROETHYLENE	127-18-4	ND	DOE 1990b							ND			
394	PHENACETIN	62-44-2	ND	DOE 1990b							ND			
395	PHENANTHRENE	85-01-8	ND	DOE 1994a		1500 µg/kg			ND					
396	PHENOL	108-95-2	ND	DOE 1994a					ND					
397	PHENYLENEDIAMINE	25265-76-3	ND	DOE 1990b							ND			
398	PHENYLTHIOUREA	103-85-5	ND	DOE 1990b							ND			
399	PHOSPHATE	7601-54-9	ND	DOE 1990b							ND	ND	ND	
400	PHOSPHORIC ACID	7664-38-2												
401	PHOSPHORUS	7723-14-0												
402	PHOSPHORUS 32													
403	PHTHALIC ACID ESTERS		ND	DOE 1990b							ND			
404	PICOLINE, 2-	109-06-8	ND	DOE 1990b							ND			
405	PLUTONIUM 238	13981-16-3				11 pCi/g	0.047 pCi/g						ND	0.00115 pCi/
406	PLUTONIUM 239	15117-48-3			0.16 pCi/g	230 pCi/g	ND						ND	0.071 pCi/g

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Table A.2. (contd)

	Name of Analyte	CAS #	Background(a)	Background Reference	SOIL 100-KR-4 (DOE 1994f)	100-HR-1 (DOE 1993c)	100-BC-1 (DOE 1994d)	100-BC-5 (DOE 1993a)	100-N (b)	1100 Area (Law 1990)	300-FF-1 (DOE 1990b)	300-FF-5 (DOE 1990a)	SEDIMENT 300-FF-5 (DOE 1990a)	100 Areas (Weiss 1993)
407	PLUTONIUM 240	14119-32-5				(w/Pu239)	ND							
408	PLUTONIUM 241	14119-32-6											ND	
409	PLUTONIUM 242	13982-10-0												
410	POLONIUM 210	13981-52-8												
411	POLONIUM 212	15389-34-1												
412	POLONIUM 216	15756-58-8												
413	POLYCHLORINATED BIPHENYLS	1336-36-3												
414	POTASSIUM	7447-40-7	2876 mg/kg	DOE 1994a	1360 mg/kg	13000 pCi/g	2130 mg/kg				1830 mg/kg	4980 mg/kg	ND	1900 mg/kg
415	POTASSIUM 40				16 pCi/g	15 pCi/g	13.85 pCi/g					ND	15 pCi/g	23 pCi/g
416	POTASSIUM CHLORATE	3811-04-9												
417	POTASSIUM CYANIDE	151-50-8												
418	POTASSIUM DICHROMATE	7778-50-9												
419	POTASSIUM FLUORIDE	7789-23-3												
420	POTASSIUM HYDROXIDE	1310-58-3												
421	POTASSIUM NITRATE	7757-79-1												
422	POTASSIUM PERMANGANATE	7722-64-7												
423	PROMETHIUM 147	7440-12-2												
424	PRONAMIDE	23950-58-5	ND	DOE 1990b							ND			
425	PROPYN-1-O1, 2-	107-19-7	ND	DOE 1990b										
426	PROTACTINIUM 231	14331-85-2												
427	PROTACTINIUM 233	13981-14-1												
428	PYRENE	129-00-0	ND	DOE 1994a		1200 µg/kg			ND					
429	PYRIDINE	110-86-1	ND	DOE 1990b							ND			
430	RADIUM	7440-14-4											ND	
431	RADIUM 223													
432	RADIUM 226	13982-63-3	ND	DOE 1990b	0.53 pCi/g	0.85 pCi/g	0.84 pCi/g					3.09 pCi/g	.71 pCi/G	1.7 pCi/g
433	RADIUM 228													ND
434	RADON 220	22481-48-7												
435	RESERPINE	50-55-5	ND	DOE 1990b							ND			
436	RESORCINOL	108-46-3	ND	DOE 1990b							ND			
437	RUTHENIUM 103	13968-53-1					ND					ND		
438	RUTHENIUM 106	13967-48-1					ND					ND	ND	ND
439	SAFROL	94-59-7	ND	DOE 1990b							ND			
440	SAMARIUM 151	15705-94-3												
441	SCANDIUM 46													
442	SECBUTYL-4,6-DINITROPHENOL													
443	SELENIUM	7782-49-2	ND	DOE 1994a			4.2 mg/kg				ND	ND	ND	
444	SELENIUM 79	15758-45-9												
445	SELENIUM CHLORIDE	10025-68-0												
446	SELENIUM NITRATE													
447	SILVER	7440-22-4	1.48 mg/kg	DOE 1994a			1.9 mg/kg				18 mg/kg	ND	ND	2.5 mg/kg
448	SILVER CHLORIDE	7783-90-6										17300 mg/kg		
449	SILVER NITRATE	7761-88-8												
450	SILVER OXIDE	20667-12-3												
451	SODIUM	7440-23-5	969 mg/kg	DOE 1994a	1770 mg/kg		779 mg/kg				401 mg/kg		ND	920 mg/kg
452	SODIUM 22	7440-23-5				ND								0.13 pCi/g
453	SODIUM ALUMINATE													
454	SODIUM CHLORIDE	7647-14-5												
455	SODIUM DICHROMATE	10588-01-9												
456	SODIUM FLUORIDE	7681-49-4												
457	SODIUM HYDROXIDE	1310-73-2												
458	SODIUM HYPOCHLORITE	7681-52-9												
459	SODIUM NITRATE	7631-99-4												
460	SODIUM PHOSPHATE, TRIBASIC	7601-54-9												
461	SODIUM SILICATE	1344-09-8												
462	SODIUM SULFATE	7757-82-6												
463	SODIUM SULFIDE	1313-82-2												
464	SODIUM THIOCYANATE	540-72-7												

Table A.2. (contd)

					SOIL								SEDIMENT	
	Name of Analyte	CAS #	Background(a)	Background Reference	100-KR-4 (DOE 1994f)	100-HR-1 (DOE 1993c)	100-BC-1 (DOE 1994d)	100-BC-5 (DOE 1993a)	100-N (b)	1100 Area (Law 1990)	300-FF-1 (DOE 1990b)	300-FF-5 (DOE 1990a)	300-FF-5 (DOE 1990a)	100 Areas (Weiss 1993)
465	STRONTIUM	10476-85-4									67 mg/kg			
466	STRONTIUM 89	14158-27-1												
467	STRONTIUM 90	10098-97-2				950 pCi/g	770 pCi/g					ND	ND	207pCi/g
468	STRONTIUM CHLORIDE	10476-85-4			1 µg/kg									
469	STRYCHNINE	57-24-9	ND	DOE 1990b							ND			
470	STYRENE	100-42-5	ND	DOE 1994a					ND			ND	ND	
471	SULFATE	12808-79-8					32 mg/kg				52 mg/kg	131 mg/kg	ND	
472	SULFIDE	18496-25-8	ND	DOE 1990b										
473	SULFUR OXIDES	20901-21-7												
474	SULFURIC ACID	7664-93-9	ND	DOE 1990b										
475	T (2,4,4)	7664-93-9												
476	SYM-TRINITROBENZENE		ND	DOE 1990b							ND			
477	T(2,4,5)	93-76-5												
478	TECHNETIUM 99	14133-76-7				0.67 pCi/g	ND						ND	0.5 pCi/g
479	TETRACHLOROBENZENE, 1,2,3,4-		ND	DOE 1990b							ND			
480	TETRACHLOROBENZENE, 1,2,3,5-		ND	DOE 1990b							ND			
481	TETRACHLOROBENZENE, 1,2,4,5-	95-94-3	ND	DOE 1990b							ND			
482	TETRACHLORODIBENZO-p-DIOXIN, 2,3,7,8-	1746-01-6												
483	TETRACHLOROETHANE, 1,1,1,2-	630-20-6	ND	DOE 1990b							ND			
484	TETRACHLOROETHANE, 1,1,2,2-	79-34-5	ND	DOE 1994a					ND		ND	ND	ND	
485	TETRAETHYL PYROPHOSPHATE	107-49-3	ND	DOE 1994a										
486	TETRACHLOROETHYLENE	127-18-4	ND	DOE 1994a					ND			ND	ND	
487	TETRACHLOROMETHANE	56-23-5												
488	TETRAHYDROFURAN	109-99-9												
489	THALLIUM	7440-28-0	ND	DOE 1994a			ND				ND	ND	ND	
490	THALLIUM 208	14913-50-9												
491	THILFANOX		ND	DOE 1990b							ND			
492	THIOUREA	62-56-6	ND	DOE 1990b										
493	THIOUREA, 1-(O-CHLOROPHENYL)-		ND	DOE 1990b										
494	THIOUREA, 1-ACETYL-2-		ND	DOE 1990b										
495	THIOUREA, 1-NAPHTHY-2-		ND	DOE 1990b										
496	THIRAM	137-26-8	ND	DOE 1990b							ND			
497	THORIUM 228					0.95 pCi/g	1.1 pCi/g					1.61 pCi/g	1.4 pCi/G	3 pCi/g
498	THORIUM 229	15595-54-4												
499	THORIUM 230	14268-63-7												
500	THORIUM 231													0.454 pCi/g
501	THORIUM 232				1.1 µg/kg	0.89 pCi/g	0.8 pCi/g					1.1 pCi/g	1.1 pCi/g	3.2 pCi/g
502	THORIUM 234						ND							0.812 pCi/g
503	TIN	7440-31-5											ND	
504	TIN 113	13966-06-8												
505	TIN 126	15832-50-5												
506	TITANIUM	7440-32-6	2925 mg/kg	DOE 1994a										
507	TITANIUM CHLORIDE	10049-06-6												
508	TOLUENE	108-88-3	ND	DOE 1994a		49 µg/kg			350 mg/kg		ND	ND	ND	
509	TOLUENEDIAMINE	496-72-0	ND	DOE 1990b							ND			
510	TOLUIDINE HYDROCHLORIDE, O-	636-21-5	ND	DOE 1990b							ND			
511	TOTAL ORGANIC CARBON		ND	DOE 1990b										
512	TOTAL ORGANIC HALIDE		ND	DOE 1990b										
513	TOTAL PETROLEUM HYDROCARBONS								125920 mg/kg					
514	TOXAPHENE	8001-35-2	ND	DOE 1994a										
515	TP(2,4,5)SILVEX	93-72-1	ND	DOE 1990b										
516	TRIBROMOMETHANE	75-25-2												
517	TRIBUTYL PHOSPHATE	126-73-8												
518	TRIBUTYLPHOSPHORIC ACID		ND	DOE 1990b							ND			
519	TRICHLOROBENZENE		ND	DOE 1990b										
520	TRICHLOROBENZENE, 1,2,3-	87-61-6	ND	DOE 1990b							ND			
521	TRICHLOROBENZENE, 1,2,4-	120-82-1	ND	DOE 1994a					ND		ND			
522	TRICHLOROBENZENE, 1,3,5-	108-70-3	ND	DOE 1990b										

Table A.2. (contd)

					SOIL								SEDIMENT	
	Name of Analyte	CAS #	Background(a)	Background Reference	100-KR-4 (DOE 1994f)	100-HR-1 (DOE 1993c)	100-BC-1 (DOE 1994d)	100-BC-5 (DOE 1993a)	100-N (b)	1100 Area (Law 1990)	300-FF-1 (DOE 1990b)	300-FF-5 (DOE 1990a)	300-FF-5 (DOE 1990a)	100 Areas (Weiss 1993)
523	TRICHLOROETHANE, 1,1,1-	71-55-6	ND	DOE 1994a					ND		ND	ND	ND	
524	TRICHLOROETHANE, 1,1,2-	79-00-5	ND	DOE 1994a					ND		ND	ND	ND	
525	TRICHLOROETHYLENE	79-01-6	ND	DOE 1994a			ND		ND		ND	ND	ND	
526	TRICHLOROMETHANETHIOL	75-70-7	ND	DOE 1990b							ND			
527	TRICHLOROMONOFLUOROMETHANE	75-96-4	ND	DOE 1990b							ND			
528	TRICHLOROPHENOL, 2,4,5-	95-95-4	ND	DOE 1994a					ND		ND			
529	TRICHLOROPHENOL, 2,4,6-	88-06-2	ND	DOE 1994a					ND		ND			
530	TRICHLOROPROPANE	25735-29-9	ND	DOE 1990b							ND			
531	TRICHLOROPROPANE, 1,2,3-	96-18-4	ND	DOE 1990b							ND			
532	TRIETHYLPHOSPHOROTHIOATE, O,O,O-	126-68-1	ND	DOE 1990b							ND			
533	TRIS (2,3 DIBROMOPROPHYL) PHOSPHATE	126-72-7	ND	DOE 1990b							ND			
534	TRITIUM (HYDROGEN 3)	10028-17-8				1600 pCi/g	ND							
535	TUNGSTEN	7440-33-7												
536	URANIUM	7440-61-1												
537	URANIUM (TOTAL ACTIVITY)											ND	ND	
538	URANIUM 233	13968-55-3			0.59 pCi/g	0.53 pCi/g	0.6 pCi/g					3.9 pCi/g		2.3 pCi/g
539	URANIUM 234	13966-29-5			(w/U233)		(w/U233)					w/U233	3.9 pCi/g	w/U233
540	URANIUM 235	15117-96-1				0.0016 pCi/g	0.02 pCi/g					0.23 pCi/g	ND	0.1 pCi/g
541	URANIUM 236	13982-70-2												
542	URANIUM 238	24678-82-8			0.59 pCi/g	4.7 pCi/g	0.62 pCi/g					3.2 pCi/g	3.2 pCi/g	2.3 pCi/g
543	VANADIUM	7440-62-2	96.7 mg/kg	DOE 1994a	55.8 mg/kg	389 mg/kg	76.9 mg/kg				73 mg/kg	ND	44.4 mg/kg	82.2 mg/kg
544	VANADIUM PENTOXIDE	13140-62-1												
545	VINYL ACETATE	108-05-4	ND	DOE 1994a					ND			ND	ND	
546	VINYL CHLORIDE	75-01-4	ND	DOE 1994a					ND		ND	ND	ND	
547	WARFARIN	81-81-2	ND	DOE 1990b							ND			
548	XYLENE	1330-20-7	ND	DOE 1994a					1800 mg/kg			ND	ND	
549	XYLENE, m-	108-38-3	ND	DOE 1990b							ND			
550	XYLENE, O,P-		ND	DOE 1990b							ND			
551	YTTRIUM 90	10098-91-6												
552	ZINC	7440-66-6	74.7 mg/kg	DOE 1994a	24.3 mg/kg	520 mg/kg	309 mg/kg				97 mg/kg	70.7 mg/kg	118 mg/kg	397 mg/kg
553	ZINC 65	13982-39-3					ND					ND	ND	0.24 pCi/g
554	ZINC AMALGAM													
555	ZINC CHLORIDE	1646-85-7												
556	ZINC COMPOUNDS	7646-85-7												
557	ZINC NITRATE	7779-88-6												
558	ZIRCONIUM	7440-67-7	45.4 mg/kg	DOE 1994a										
559	ZIRCONIUM 93	15751-77-6												
560	ZIRCONIUM 95	13967-71-0				0.56 pCi/g	ND					ND		

(a) Provisional values estimated to be the background concentrations.
(b) Hartman and Lindsey (1993); Rowley 1993.

Table A.3. Maximum Detected Concentrations in Groundwater in the Hanford Site 100, 200, and 600 Areas Away from the Columbia River, 1980-1994

Name of Analyte	Number of Plumes	Concentration
100 Areas		
Chromium (+6)	3	1,570 ppb
Nitrate	10	130,000 ppb
Strontium-90	8	1,800 pCi/L
Tritium (Hydrogen-3)	4	80,000 pCi/L
200 West Area		
Arsenic	4	24 ppb
Carbon Tetrachloride	1	6,559 ppb
Chloroform	2	1,595 ppb
Chromium	5	323 ppb
Fluoride	3	10,067 ppb
Iodine-129	2	30 pCi/L
Nitrate	5	1,322,000 ppb
Technetium-99	5	26,602 pCi/L
Trichloroethylene	3	32 ppb
Tritium (Hydrogen-3)	3	6,193,000 pCi/L
Uranium	4	1,616 pCi/L
200 East Area		
Arsenic	4	24ppb
Cesium-137	1	1,326 pCi/L
Chloroform	1	7 ppb
Chromium	4	288 ppb
Cobalt-60	2	440 pCi/L
Cyanide	2	893 ppb
Iodine-129	3	20 pCi/L
Nitrate	7	397,000 ppb
Plutonium-239/240	1	69 pCi/L
Strontium-90	5	5,149 pCi/L
Technetium-99	2	22,163 pCi/L
Tritium (Hydrogen-3)	5	4,126,000 pCi/L
Uranium	1	27 pCi/L
600 Area (Solid Waste Landfill Site)		
Chloroform	1	0.5 ppb
Dichloroethane, 1, 1-	1	7 ppb
Tetrachloroethene	1	12 ppb
Trichloroethane, 1, 1, 1-	1	50 ppb
Trichloroethene	1	7 ppb

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Appendix B

Parameter Values Used in Screening Analyses

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Appendix B

Parameter Values Used in Screening Analyses

The equations detailed in Section 4.0 require parameters for each radionuclide and chemical evaluated. The parameters used to screen samples from the Columbia River and groundwater within 150 meters (500 feet) of the Columbia River are provided in Table B.1. The parameters used to screen samples of soil and sediment are provided in Table B.2. The parameters used to screen samples of groundwater farther than 150 meters (500) feet from the Columbia River are provided in Table B.3.

The following abbreviations are used in the tables:

LC50	=	lowest concentration reported to be lethal to aquatic life, as reported in EPA 1985.
RfD	=	EPA chronic oral reference dose value.
TLM	=	lowest concentration below which no effects on aquatic life are observed, as reported in EPA 1985.

Table B.1. Parameters Used to Screen Columbia River and Groundwater Near the Columbia River

	Name of Analyte	Maximum Concentration in Surface Water	Maximum Concentration in Groundwater	Ingestion Slope Factor (Risk/pCi)	External Slope Factor (Risk/pCi)	RfD (mg/kg/day)	Cancer Potency Factor (1)/(mg/kg/day)	Fish Bioaccumulation (L/kg)	LC50 (μg/L)	TLM (μg/L)	Notes on Fish Toxicity	Water Quality Criteria (μg/L)
1	ACETONE	11 μg/L	30 μg/L			0.1		0.2		4,000,000		
2	ALUMINUM		4,810 μg/L			0.0004		10	5,000		8	
3	AMERICIUM 241		0.021 pCi/L	2.40E-10	4.90E-09			250				
4	AMMONIA		70 μg/L			0.029		0.2	1,800		as ammonium	
5	AMMONIUM		1,630 μg/L			0.09		0.2		1,800	9	
6	ANTIMONY		60 μg/L			0.0004		200				
7	ANTIMONY 125		20 pCi/L	8.40E-13	1.20E-06			200				
8	ARSENIC	3.4 μg/L	17 μg/L			0.0003	1.75	100	1,100			190
9	BARIUM	46.2 μg/L	719 μg/L			0.07		200	400,000			
10	BERYLLIUM		6 μg/L			0.005	4.3	19	200			
11	BERYLLIUM 7										10	
12	BIS(2-ETHYLHEXYL) PHTHALATE		50 μg/L			0.02	0.014	70		32,000		
13	BISMUTH											
14	BORON		64 μg/L			0.09						
15	CADMIUM		31 μg/L			0.0005	6.3	200		30,000		1.1
16	CALCIUM	35,900 μg/L	302,000 μg/L									
17	CARBON 14		23,000 pCi/L	9.00E-13	0			4600				
18	CESIUM 134	0.012 pCi/L		4.10E-11	5.20E-06			2000				
19	CESIUM 137	0.13 pCi/L	0.5 pCi/L	2.80E-11	2.00E-06			2000				
20	CHLORIDE	870 μg/L	122,000 μg/L					50				
21	CHLOROFORM		42 μg/L			0.01	0.006	100	100,000			
22	CHROMIUM	22 μg/L	1,950 μg/L			1	41	200	1,000			11
23	COBALT		8 μg/L			0.0081		50		10,000,000		
24	COBALT 60	0.011 pCi/L	140 pCi/L	1.50E-11	8.60E-06			330				
25	COPPER	22 μg/L	616 μg/L			0.0003		50	500			12
26	CYANIDE		21.1 μg/L			0.02		0.2				5.2
27	DICHLOROETHYLENE, 1,2-		200 μg/L				0.009	2.9		5000		
28	DICHLOROETHYLENE, 1,2-trans-		130 μg/L			0.02	1.2	20				
29	EUROPIUM 154		2 pCi/L	3.00E-12	4.10E-06			25				
30	FLUORIDE	150 μg/L	2,080 μg/L			0.06		10		2,300	11	
31	HYDRAZINE		7 μg/L				3	0.5		2,000		
32	IODINE 129	0.16 pCi/L		1.90E-10	4.10E-09			15				
33	IRON	463 pCi/L	37,300 μg/L			1.3		2000				
34	LEAD		173 μg/L			0.0014		100		530		3.2
35	LITHIUM											
36	MAGNESIUM	9,860 μg/L	55,000 μg/L			50		50				
37	MANGANESE	22.8 μg/L	400 μg/L			0.07		400		500,000	12	
38	MERCURY		8.9 μg/L			0.0003		1000	10			0.012
39	METHYL ETHYL KETONE		18 μg/L			1		50	5,600,000			
40	METHYLENE CHLORIDE		3,040 μg/L			0.06	0.0075	2.5	550,000		13	
41	NICKEL	31μg/L	479 μg/L			0.02		100		380		160

Table B.1. (contd)

	Name of Analyte	Maximum Concentration In Surface Water	Maximum Concentration In Groundwater	Ingestion Slope Factor (Risk/pCi)	External Slope Factor (Risk/pCi)	RfD (mg/kg/day)	Cancer Potency Factor (1)/(mg/kg/day)	Fish Bioaccumulation (L/kg)	LC50 (µg/L)	TLM (µg/L)	Notes on Fish Toxicity	Water Quality Criteria (µg/L)
42	NITRATE	480 µg/L	90,000 µg/L			1.6		150000	20,000		1	
43	NITRITE		60,000 µg/L			0.034		150000	20,000		as nitrate	
44	PHOSPHATE		3,240 µg/L			0.46		70000		59,000	2	
45	PLUTONIUM 238		0.01 pCi/L	2.20E-10	2.80E-11			250				
46	PLUTONIUM 239		0.03 pCi/L	2.30E-10	1.70E-11			250				
47	POTASSIUM	2,430 µg/L	11,300 µg/L			510		1000	80,000		3	
48	RADIUM 226		0.3 pCi/L	1.20E-10	1.20E-08			70				
49	RUTHENIUM 106+D		34.4 pCi/L	9.50E-12	6.70E-07			100				
50	SELENIUM		17.2 µg/L			0.005		170		2,500		5
51	SILICON											
52	SILVER		19 µg/L			0.005			4			
53	SODIUM	13,800 µg/L	200,000 µg/L			300		100		4,720,000		
54	STRONTIUM		310 µg/L			0.6		50		200,000		
55	STRONTIUM 90	28 pCi/L	80,000 pCi/L	3.30E-11	0			50				
56	SULFATE	8,600 µg/L	600,000 µg/L			71		750		80,000	4	
57	SULFIDE		3,000 µg/L							80,000	4	
58	TECHNETIUM 99		2,270 pCi/L	1.30E-12	6.00E-13			15				
59	TETRACHLOROETHYLENE		39 µg/L				0.051	100	18000			
60	THALLIUM		4 µg/L					10000	40			
61	THORIUM 228		3 pCi/L	5.50E-11	5.56E-06			100				
62	THORIUM 232		44.5 pCi/L	1.20E-11	2.60E-11			100				
63	TITANIUM								will smother		5	
64	TOLUENE	4.7 µg/L	2.9 µg/L			0.2		50	60000			
65	TRICHLOROETHYLENE		24.1 µg/L				0.011	11	55,000			
66	TRITIUM (HYDROGEN 3)	4,430 pCi/L	,900,000 pCi/L	5.40E-14	0			1				
67	URANIUM 233		3.3 pCi/L	1.60E-11	4.20E-11			50			6	
68	URANIUM 234	18 pCi/L	120 pCi/L	1.60E-11	3.00E-11			50			6	
69	URANIUM 235	0.01 pCi/L	17 pCi/L	1.60E-11	2.40E-07			50				
70	URANIUM 238	19 pCi/L	93 pCi/L	1.60E-11	2.10E-11			50				
71	VANADIUM		40 µg/L							55,000	7	
72	XYLENE	4 µg/L				2		150		4,000		
73	ZINC	11 µg/L	8,800 µg/L			0.3		2500	430			110

	Notes on Fish Toxicity		
1	assume ferric nitrate	8	aluminum hydroxide
2	phosphate of soda	9	ammonium hydroxide
3	potassium hydroxide	10	assume beryllium
4	sulfur	11	assume fluorine
5	titanium dioxide	12	manganese 54
6	U235	13	chloromethane
7	vanadium pentoxide		

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Table B.2. Parameters Used to Screen Soil and Sediment

	Name of Analyte	Maximum Concentration in Soil	Maximum Concentration in Sediment	Ingestion Slope Factor (Risk/pCi)	External Slope Factor (Risk/pCi)	RfD (mg/kg/day)	Cancer Potency Factor (1)/(mg/kg/day)	Fish Bioaccumulation (L/kg)	LC50 (μg/L)	TLM (μg/L)	Notes on Fish Toxicity	Water Quality Criteria (μg/L)
	Radionuclides											
1	AMERICIUM 241	34 pCi/g		2.40E-10	4.90E-09			250				
2	ANTIMONY 124		1.2 pCi/g	2.90E-12	6.50E-06			200				
3	CARBON 14	34 pCi/g		9.00E-13	0			4,600				
4	CESIUM 134	0.04 pCi/g	0.29 pCi/g	4.10E-11	5.20E-06			2,000				
5	CESIUM 137	2,900 pCi/g	6 pCi/g	2.80E-11	2.00E-06			2,000				
6	COBALT 60	18,000 pCi/g	4.9 pCi/g	1.50E-11	8.60E-06			330				
7	EUROPIUM 152	59,000 pCi/g	2.41 pCi/g	2.10E-12	3.60E-06			25				
8	EUROPIUM 154	20,000 pCi/g	0.24 pCi/g	3.00E-12	4.10E-06			25				
9	EUROPIUM 155	6,200 pCi/g	0.32 pCi/g	4.50E-13	5.90E-08			25				
10	NEPTUNIUM 237		0.606 pCi/g	2.20E-10	7.80E-09			250				
11	NICKEL 63	20,000 pCi/g		2.40E-13	0			100				
12	PLUTONIUM 238	11 pCi/g	0.00115 pCi/g	2.20E-10	2.80E-11			250				
13	PLUTONIUM 239	230 pCi/g	0.071 pCi/g	2.30E-10	1.70E-11			250				
14	PLUTONIUM 240	(w/Pu239)		2.30E-10	2.70E-11			250				
15	POTASSIUM 40	16 pCi/g	23 pCi/g	1.10E-11	5.40E-07			1,000				
16	RADIUM 226	3.09 pCi/g	1.7 pCi/g	1.20E-10	1.20E-08			70				
17	STRONTIUM 90	950 pCi/g	207 pCi/g	3.30E-11	0			50				
18	TECHNETIUM 99	0.67 pCi/g	0.5 pCi/g	1.30E-12	6.00E-13			15				
19	THORIUM 228	1.61 pCi/g	3 pCi/g	1.10E-11	5.50E-10			100				
20	THORIUM 232	1.1 pCi/g	3.2 pCi/g	1.20E-11	2.80E-11			100				
21	THORIUM 234	ND	0.812 pCi/g	4.00E-12	3.50E-09			100				
22	TRITIUM (HYDROGEN 3)	1,600 pCi/g		5.40E-14	0			3,000				
23	URANIUM 233	3.9 pCi/g	2.3 pCi/g	1.60E-11	4.20E-11			50				
24	URANIUM 234		3.9 pCi/g	1.60E-11	3.00E-11			50				
25	URANIUM 235	1.23 pCi/g	0.1 pCi/g	1.60E-11	2.40E-07			50				
26	URANIUM 238	4.7 pCi/g	3.2 pCi/g	1.60E-11	2.10E-11			50				
27	ZINC 65	ND	0.24 pCi/g	8.50E-12	2.00E-06			2,500				
28	ZIRCONIUM 95	0.56 pCi/g		9.90E-13	2.50E-06			200				
	Chemicals											
29	ACENAPHTHENE	210 μg/kg				0.06		300	4,000		1	
30	ALUMINUM	26,700,000 μg/kg	9,350,000 μg/kg			0.004		10	5,000		7	
31	AMMONIA	12,800 μg/kg	12,000 μg/kg			0.029		0	1,800			
32	ANTHRACENE	430 μg/kg				0.3		3,000	4,000		1	
33	AROCLOR 1248 (PCB)	9,900 μg/kg					7.7	10,000		278		0.014
34	ARSENIC	47,000 μg/kg	7,500 μg/kg			0.0003	1.75	100	1,100			190

Table B.2. (contd)

	Name of Analyte	Maximum Concentration in Soil	Maximum Concentration in Sediment	Ingestion Slope Factor (Risk/pCi)	External Slope Factor (Risk/pCi)	RfD (mg/kg/day)	Cancer Potency Factor (1)/(mg/kg/day)	Fish Bioaccumulation (L/kg)	LC50 (µg/L)	TLM (µg/L)	Notes on Fish Toxicity	Water Quality Criteria (µg/L)
35	BARIUM	672,000 µg/kg	120,000 µg/kg			0.07		200	400,000			
36	BENZENE	4,500 µg/kg					0.029	10		20		
37	BENZO(G,H,I)PERYLENE	410 µg/kg							4,000		1	
38	BENZO[a]ANTHRACENE	940 µg/kg					0.84	12,000	4,000		1	
39	BENZO[a]PYRENE	810 µg/kg					5.79	20,000	4,000		1	
40	BENZO[b]FLUORANTHENE	890 µg/kg					0.81	20,000	4,000		1	
41	BENZO[K]FLUORANTHENE	760 µg/kg					0.38	20,000	4,000		1	
42	BENZOIC ACID	1,700 µg/kg				4		6	180,000			
43	BERYLLIUM	8,000 µg/kg	1,100 µg/kg			0.005	4.3	19	200			
44	BIS(2-ETHYLHEXYL) PHTHALATE	68,000 µg/kg				0.02	0.014	70		32,000		
45	CADMIUM	1,800 µg/kg	2,700 µg/kg			0.0005	6.3	200		30,000		1.1
46	CALCIUM	40,800,000 µg/kg	4,460,000 µg/kg									
47	CHLORDANE	4,500 µg/kg				0.00006	1.3	322	8			0.0043
48	CHLORIDE	1,100 µg/kg				0.011		50				
49	CHLORINE (a)											
50	CHROMIUM	259,000 µg/kg	12,200 µg/kg			1	41	200	1,000			11
51	CHRYSENE	920 µg/kg					0.0255	20,000	4,000		1	
52	COBALT	34,100 µg/kg	11,500 µg/kg			0.0081		50		10,000,000		
53	COPPER	40,000,000 µg/kg	40,000 µg/kg			0.0003		50	500			12
54	CYANIDE	1,050 µg/kg				0.02		0				5.2
55	DIBENZOFURAN	130 µg/kg										
56	DIESEL FUEL	2,800,000 µg/kg				0.36		300	1,000			
57	ENDRIN ALDEHYDE	3.3 µg/kg				0.0003		1,480	0		2	
58	ETHYL BENZENE	32,000 µg/kg				0.1		100		30		
59	FLUORANTHENE	1,800µg/kg				0.04		3,000	4,000		1	
60	FLUORENE	190 µg/kg				0.04		713	4,000		1	
61	FLUORIDE	4,700 µg/kg				0.04		10		2,300	3	
62	FLUORINE (a)											
63	INDENO(1,2,3-CD)PYRENE	520 µg/kg					1.34	40,000	4,000		1	
64	IRON	33,500,000 µg/kg	71,000,000 µg/kg			1.3		2,000				
65	KEROSENE	3,085,000 µg/kg				0.7		300		200		
66	LEAD	540,000 µg/kg	73,000 µg/kg			0.0014		100		530		3.2
67	LITHIUM (a)											
68	MAGNESIUM	11,600,000 µg/kg	7,600,000 µg/kg									
69	MANGANESE	839,000 µg/kg	578,000 µg/kg							500,000		
70	MERCURY	4,300 µg/kg				0.0003		1,000	10			0.012

Table B.2. (contd)

	Name of Analyte	Maximum Concentration in Soil	Sediment	Ingestion Slope Factor (Risk/pCi)	External Slope Factor (Risk/pCi)	RfD (mg/kg/day)	Cancer Potency Factor (1)/(mg/kg/day)	Fish Bioaccumulation (L/kg)	LC50 (µg/L)	TLM (µg/L)	Notes on Fish Toxicity	Water Quality Criteria (µg/L)
71	METHYL-2-PENTANONE, 4-	22,000 µg/kg										
72	METHYLENE CHLORIDE	120 µg/kg				0.06	0.0075	3	550,000		4	
73	METHYLNAPHTHALENE, 2-	42 µg/kg							4,000		1	
74	NICKEL	221,000 µg/kg	19,700 µg/kg			0.02		100		380		160
75	NITRATE	30,400 µg/kg				1.6		150,000	20,000		5	
76	PHENANTHRENE	1,500 µg/kg				0.04		1,000	4,000		1	
77	POTASSIUM	4,980,000 µg/kg	1,900,000 µg/kg						80,000			
78	PYRENE	1,200 µg/kg				0.03		2,800	4,000		1	
79	SELENIUM	4,200 µg/kg				0.005		170	2,500			5
80	SILVER	1,900 µg/kg	2,500 µg/kg						4			
81	SILVER CHLORIDE	17,300,000 µg/kg				0.005		2				
82	SODIUM	1,770,000 µg/kg	920,000 µg/kg							4,720,000		
83	STRONTIUM	67,000 µg/kg				0.6		50		200,000	6	
84	STRONTIUM CHLORIDE	1 µg/kg				0.6		50		200,000		
85	SULFATE (SULFUR)	131,000 µg/kg				71		750		80,000		
86	TITANIUM (a)											
87	TOLUENE	350,000 µg/kg				0.2		20	60,000			
88	TOTAL PETROLEUM HYDROCARBON	1.26E+08										
89	VANADIUM	389,000 µg/kg	82,200 µg/kg							55,000		
90	XYLENE	1,800,000 µg/kg				0.2		150		4,000		
91	ZINC	309,000 µg/kg	397,000 µg/kg			0.3		2,500	430			110
92	ZIRCONIUM (a)											
(a)	Concentrations of these chemcials fall within their respectively occurring background levels.											
	Notes on Fish Toxicity											
1	assume naphthalene											
2	assume endrine											
3	assume fluorine											
4	assume chloromethane											
5	assume ferric nitrate											
6	assume strontium chloride											
7	assume aluminum hydroxide											

Table B.3. Parameters Used to Screen Groundwater Away from the Columbia River

Name of Analyte	Number of Plumes	Maximum Concentration	Reference	Ingestion Slope Factor (Risk/pCi)	External Slope Factor (Risk/pCi)	RfD (mg/kg/day)	Cancer Potency Factor (mg/kg/day)	Fish Bioaccumulation (L/kg)	LC50 (µg/L)	TLM (µg/L)	Water Quality Criteria (µg/L)
100 Areas											
Chromium (+6)	3	1,570 ppb	DOE 1994b			1	41	200	1,000		11
Nitrate	10	130,000 ppb	DOE 1994b			2		150,000	20,000		
Strontium-90	8	1,800 pCi/L	DOE 1994b	0	0			50			
Tritium (Hyrdrogen-3)	4	80,000 pCi/L	DOE 1994b	0	0			1			
200 West Area											
Arsenic	4	24 ppb	Ford 1993			0	2	100	1,100		190
Carbon Tetrachloride	1	6,559 ppb	Ford 1993			0	0	150	125,000		
Chloroform	2	1,595 ppb	Ford 1993			0	0	100	100,000		
Chromium	5	323 ppb	Ford 1993			1	41	200	1,000		11
Fluoride	3	10,067 ppb	Ford 1993			0		10		2,300	
Iodine-129	2	30 pCi/L	Ford 1993	0	0			15			
Nitrate	5	1,322,000 ppb	Ford 1993			2		150,000	20,000		
Technetium-99	5	26,602 pCi/L	Ford 1993	0	0			15			
Trichloroethylene	3	32 ppb	Ford 1993				0	11	55,000		
Tritium (Hydrogen-3)	3	6,193,000 pCi/L	Ford 1993	0	0			1			
Uranium	4	1,616 pCi/L	DOE 1994b	0	0			50			
200 East Area											
Arsenic	4	24 ppb	Ford 1993			0	2	100	1,100		190
Cesium-137	1	1,326 pCi/L	Ford 1993	0	0			2,000			
Chloroform	1	7 ppb	DOE 1994b			0	0	100	100,000		
Chromium	4	288 ppb	Ford 1993			1	41	200	1,000		11
Cobalt-60	2	440 pCi/L	Ford 1993	0	0			330			
Cyanide	2	893 ppb	Ford 1993			0		0			5
Iodine-129	3	20 pCi/L	Ford 1993	0	0			15			
Nitrate	7	397,000 ppb	Ford 1993			2		150,000	20,000		
Plutonium-239/240	1	69 pCi/L	Ford 1993								
Strontium-90	5	5,149 pCi/L	Ford 1993	0	0			50			
Technetium-99	2	22,163 pCi/L	Ford 1993	0	0			15			
Tritium (Hydrogen-3)	5	4,126,000 pCi/L	Ford 1993	0	0			1			
Uranium	1	27 pCi/L	Ford 1993	0	0			50			
600 Area (Solid Waste Landfill Site)											
Chloroform	1	0.5 ppb	DOE 1994b			0	0	100	100,000		
Dichloroethane, 1, 1-	1	7 ppb	DOE 1994b			0		7	220,000		
Tetrachloroethene	1	12 ppb	DOE 1994b			0	0	100	13,000		
Trichloroethane, 1, 1, 1-	1	50 ppb	DOE 1994b			0	0	39	50,000		
Trichloroethene	1	7 ppb	DOE 1994b				0	52	55,000		

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Appendix C

Complete Numerical Results

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Appendix C

Complete Numerical Results

This appendix provides the numerical results of applying the screening equations in Section 4.0 to the detected analytes described in Sections 3.0 and 7.0. Table C.1 presents the numerical results of screening samples at the Columbia River and groundwater within 150 meters (500 feet) of the Columbia River. Table C.2 presents the numerical results of screening soil and sediment samples. Table C.3 presents the numerical results of screening samples from groundwater farther than 150 meters (500 feet) from the Columbia River. Application of the equations and assumptions defined in Section 4.0 results in a series of complementary, but not necessarily intercomparible, screening values for each contaminant. The varying numbers of assumptions and associated varying degrees of conservatism require that each of the screenings be evaluated separately. The results of the combined screenings, however, then define the overall list of contaminants of concern.

Each table includes a "notes" column. The notes consist of abbreviated designations. The following are the full descriptions of each designation as well as explanations of the column headings.

Bkg	= background denotes that the highest concentration found was at background level so eliminated from consideration.
EPA-10	= eliminated based on the guidance in *EPA Region 10 Supplemental Risk Assessment Guidance for Superfund* (EPA 1991).
I	= parameters derived from the Integrated Risk Information System (IRIS) database (EPA 1994b).
Inadequate?	= insufficient information available to classify as toxic or having carcinogenic properties.
LC50/100	= lowest concentration reported to be lethal to aquatic life 100 days after exposure, as reported in EPA 1985.
LD	= near limit of detection.
M	= parameters derived from the Multimedia Environmental Pollutant Assessment System (MEPAS) database (Droppo et al. 1991).
ND	= not detected.
Non-Haz.?	= analyte not designated in database as containing hazardous properties.
Suspect	= noted in the source database as being unreliable (see Section 4.4).
SW	= surface water (Columbia River water).
SW-LD	= reported sample in surface water very near the limit of detection and, therefore, unreliable.
T 1/2	= half-life of analyte indicates that any concentration present at sampling should now be decayed to insignificance.
TLM	= lowest concentration below which no effects on aquatic life are observed, as reported in EPA 1985.
Unclass?	= not classified in MEPAS or IRIS as hazardous.
WQC	= water quality criteria.

Table C.1. Results for the Columbia River and Groundwater Near the Columbia River

			Carcinogenic Risk Ranking		Hazard Index Ranking		WQC Screen Ranking		LC50/100 Screen Ranking		TLM Screen Ranking	
	Name of Analyte	Notes	Surface Water	Ground-water	Surface Water	Ground-water	Surface Water	Ground-water	Surface Water	Ground-water	Surface Water	Ground-water
1	ACETONE	M, SW-LD			4.80E-03	1.31E-05					2.75E-04	7.50E-09
2	ALUMINUM	M,EPA-10										
3	AMERICIUM 241			1.42E-10								
4	AMMONIA					1.05E-04				3.89E-03		
5	AMMONIUM	M				7.90E-04						9.06E-04
6	ANTIMONY					1.24E-01						
7	ANTIMONY 125			2.40E-06								
8	ARSENIC	I	2.58E-03	1.29E-05	4.92E+00	2.46E-02	1.79E-02	8.95E-05	3.09E-01	1.55E-03		
9	BARIUM	I, SW-Bkg				8.48E-03			1.21E-02	1.80E-04		
10	BERYLLIUM	I		3.02E-06		1.41E-04				3.00E-03		
11	BERYLLIUM 7	Bkg										
12	BIS(2-ETHYLHEXYL) PHTHALATE	I		2.22E-07		7.92E-04						1.56E-06
13	BISMUTH	Bkg,M										
14	BORON	Bkg,I										
15	CADMIUM	I		1.61E-04		5.12E-02		2.82E-02				1.03E-06
16	CALCIUM	Bkg,M,EPA-10										
17	CARBON 14			9.54E-06								
18	CESIUM 134		6.34E-06									
19	CESIUM 137		2.67E-05	1.03E-07								
20	CHLORIDE	M, SW-Bkg										
21	CHLOROFORM	I		1.09E-07		1.82E-03				4.20E-05		
22	CHROMIUM	I, SW-LD		6.60E-02		1.61E-03		1.77E-01		1.95E-01		
23	COBALT	M				2.36E-04						
24	COBALT 60		9.47E-06	1.20E-04								
25	COPPER	M, SW-LD			1.75E+01	4.10E-01	1.83E+00	4.30E-02	4.40E+00	1.03E-01		
26	CYANIDE	M				4.60E-05		4.06E-03				
27	DICHLOROETHYLENE, 1,2-	I		9.76E-08								4.00E-05
28	DICHLOROETHYLENE, 1,2-trans-	I		1.89E-05		7.87E-04						
29	EUROPIUM 154			8.20E-07								
30	FLUORIDE	M, SW-Bkg				2.84E-03						9.04E-04
31	HYDRAZINE			9.41E-07								3.50E-06

Table C.1. (contd)

			Carcinogenic Risk Ranking		Hazard Index Ranking		WQC Screen Ranking		LC50/100 Screen Ranking		TLM Screen Ranking	
	Name of Analyte	Notes	Surface Water	Ground-water	Surface Water	Ground-water	Surface Water	Ground-water	Surface Water	Ground-water	Surface Water	Ground-water
32	IODINE 129		1.44E-07									
33	IRON	M,EPA-10										
34	LEAD	M				5.37E-02		5.41E-02				3.26E-04
35	LITHIUM	Bkg,M										
36	MAGNESIUM	M,EPA-10										
37	MANGANESE	M			5.24E-01	9.19E-03					4.56E-03	8.00E-07
38	MERCURY	M				1.17E-01		7.42E-01		8.90E-02		
39	METHYL ETHYL KETONE	I				4.29E-06				3.21E-07		
40	METHYLENE CHLORIDE	I		1.20E-06		2.67E-03				5.53E-04		
41	NICKEL	M, SW-LD			6.73E-01	1.04E-02	1.94E-01	2.99E-03			8.16E+00	1.26E-03
42	NITRATE	M			1.76E+02	3.30E+01			2.40E+00	4.50E-01		
43	NITRITE					1.04E+03				3.00E-01		
44	PHOSPHATE	M				1.93E+00						5.49E-05
45	PLUTONIUM 238			5.74E-11								
46	PLUTONIUM 239			1.80E-10								
47	POTASSIUM	Bkg,M,EPA-10										
48	RADIUM 226			6.51E-10								
49	RUTHENIUM 106+D			2.31E-06								
50	SELENIUM	M				2.44E-03		3.44E-03				6.88E-06
51	SILICON	Bkg,M										
52	SILVER	Bkg,I										
53	SODIUM	M,EPA-10										
54	STRONTIUM	M				1.23E-04						1.55E-06
55	STRONTIUM 90		5.63E-06	1.61E-05								
56	SULFATE	M, SW-Bkg				2.52E-02						7.50E-03
57	SULFIDE											3.75E-05
58	TECHNETIUM 99			7.79E-09								
59	TETRACHLOROETHYLENE	M		8.64E-07						2.17E-04		
60	THALLIUM									1.00E-02		
61	THORIUM 228			1.67E-06								
62	THORIUM 232			6.04E-09								

Table C.1. (contd)

	Name of Analyte	Notes	Carcinogenic Risk Ranking		Hazard Index Ranking		WQC Screen Ranking		LC50/100 Screen Ranking		TLM Screen Ranking	
			Surface Water	Groundwater	Surface Water	Groundwater	Surface Water	Groundwater	Surface Water	Groundwater	Surface Water	Groundwater
63	TITANIUM	Bkg,M										
64	TOLUENE	SW sample suspect			5.61E-03	3.46E-06			7.83E-03	4.83E-06		
65	TRICHLOROETHYLENE	M		2.28E-08						4.38E-05		
66	TRITIUM (HYDROGEN 3)		2.86E-07	1.23E-07								
67	URANIUM 233			3.36E-10								
68	URANIUM 234		1.81E-06	1.21E-08								
69	URANIUM 235		2.41E-07	4.10E-07								
70	URANIUM 238		1.89E-06	9.26E-09								
71	VANADIUM	Bkg,M										7.27E-07
72	XYLENE	SW sample suspect			1.26E-03						1.00E-01	
73	ZINC	M, SW-LD			3.60E-01	2.88E-01	1.00E-01	8.00E-02	2.56E+00	2.05E+00		

Table C.2. Results for Soil and Sediment

			Carcinogenic Risk Ranking		Hazard Index Ranking		WQC Screen Ranking		LC50/100 Screen Ranking		TLM Screen Ranking	
	Name of Analyte	Notes	Soil	Sediment	Soil	Sediment	Soil	Sediment	Soil	Sediment	Soil	Sediment
	Radionuclides											
1	AMERICIUM 241		2.30E-06									
2	ANTIMONY 124	T 1/2 = 60d										
3	CARBON 14		1.41E-07									
4	CESIUM 134		2.11E-07	1.53E-06								
5	CESIUM 137		5.96E-03	1.23E-05								
6	COBALT 60		1.55E-01	4.22E-05								
7	EUROPIUM 152		2.12E-01	8.68E-06								
8	EUROPIUM 154		8.20E-02	9.84E-07								
9	EUROPIUM 155		3.66E-04	1.89E-08								
10	NEPTUNIUM 237			3.95E-08								
11	NICKEL 63		5.33E-07									
12	PLUTONIUM 238		6.32E-07	6.61E-11								
13	PLUTONIUM 239		1.38E-05	4.26E-09								
14	PLUTONIUM 240											
15	POTASSIUM 40	Bkg										
16	RADIUM 226		6.71E-08	3.69E-08								
17	STRONTIUM 90		1.91E-06	4.16E-07								
18	TECHNETIUM 99		2.30E-11	1.72E-11								
19	THORIUM 228		2.85E-09	5.31E-09								
20	THORIUM 232		1.49E-09	4.34E-09								
21	THORIUM 234			3.20E-09								
22	TRITIUM (HYDROGEN 3)		2.60E-07									
23	URANIUM 233		3.97E-09	2.34E-09								
24	URANIUM 234			3.92E-09								
25	URANIUM 235		2.96E-07	2.41E-08								
26	URANIUM 238		4.68E-09	3.19E-09								
27	ZINC 65	Suspect		4.85E-07								
28	ZIRCONIUM 95		1.40E-06									
	Chemicals											
29	ACENAPHTHENE	M			4.26E-05				5.25E-05			
30	ALUMINUM	Bkg,M,EPA-10										
31	AMMONIA	M			1.93E-04	1.81E-04			7.11E-03	6.67E-03		

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Table C.2. (contd)

	Name of Analyte	Notes	Carcinogenic Risk Ranking		Hazard Index Ranking		WQC Screen Ranking		LC50/100 Screen Ranking		TLM Screen Ranking	
			Soil	Sediment	Soil	Sediment	Soil	Sediment	Soil	Sediment	Soil	Sediment
32	ANTHRACENE	M			1.69E-04				1.08E-04			
33	AROCLOR 1248 (PCB)	M	2.99E-02				7.07E+00				3.56E-04	
34	ARSENIC	I	3.57E-04	5.70E-05	6.80E-01	1.09E-01	2.47E-03	3.95E-04		6.82E-03		
35	BARIUM	SD-Bkg,I			7.93E-02				1.68E-03			
36	BENZENE	M	1.07E-07								2.25E-03	
37	BENZO(G,H,I)PERYLENE	Non-Haz?,M							1.03E-04			
38	BENZO[a]ANTHRACENE	M	3.71E-04						2.35E-04			
39	BENZO[a]PYRENE	M,Suspect	3.67E-03						2.03E-04			
40	BENZO[b]FLUORANTHENE	M	5.65E-04						2.23E-04			
41	BENZO[K]FLUORANTHENE	M	2.26E-04						1.90E-04			
42	BENZOIC ACID	M			2.82E-07				9.44E-06			
43	BERYLLIUM	I	4.03E-05	5.54E-06	1.88E-03	2.58E-04			4.00E-02	5.50E-03		
44	BIS(2-ETHYLHEXYL) PHTHALATE	I	3.02E-06		1.08E-02							
45	CADMIUM	I	9.36E-05	1.40E-04	2.97E-02	4.46E-02	1.64E-02	2.45E-02			6.00E-07	9.00E-07
46	CALCIUM	Bkg,M,EPA-10										
47	CHLORDANE	I	7.62E-05		9.77E-01		1.05E+01		5.49E-01			
48	CHLORIDE	Bkg,M										
49	CHLORINE (a)	Bkg,I										
50	CHROMIUM	I	8.77E-02	4.13E-02	2.14E-03	1.01E-03	2.35E-01	1.11E-01		1.22E-01		
51	CHRYSENE	M	1.84E-05									
52	COBALT	M			1.00E-02	3.39E-03					3.41E-08	1.15E-08
53	COPPER	M			1.11E+03	3.18E-01	1.17E+02	3.33E-02		8.00E-02		
54	CYANIDE	M			2.29E-05		2.02E-03					
55	DIBENZOFURAN	Inadequate?,M										
56	DIESEL FUEL	M			9.47E-02				2.80E+00			
57	ENDRIN ALDEHYDE	M			6.42E-04				1.65E-02			
58	ETHYL BENZENE	M			1.39E-03						1.07E-02	
59	FLUORANTHENE	I			5.30E-03				4.50E-04			
60	FLUORENE	I			1.35E-04				4.75E-05			
61	FLUORIDE	M			9.63E-05						2.04E-05	
62	FLUORINE (a)	Bkg,I										
63	INDENO(1,2,3-CD)PYRENE	M, Suspect	1.09E-03						1.30E-04			
64	IRON	M,EPA-10										

Table C.2. (contd)

	Name of Analyte	Notes	Carcinogenic Risk Ranking Soil	Carcinogenic Risk Ranking Sediment	Hazard Index Ranking Soil	Hazard Index Ranking Sediment	WQC Screen Ranking Soil	WQC Screen Ranking Sediment	LC50/100 Screen Ranking Soil	LC50/100 Screen Ranking Sediment	TLM Screen Ranking Soil	TLM Screen Ranking Sediment
65	KEROSENE	M			5.36E-02						1.54E-01	
66	LEAD	M			1.67E+00	2.26E-01	1.69E+00	2.28E-01			1.02E-02	1.38E-03
67	LITHIUM (a)	Bkg,M										
68	MAGNESIUM	Bkg,M,EPA-10										
69	MANGANESE	Bkg,M										
70	MERCURY	M			5.67E-01		3.58E+00		4.30E-01			
71	METHYL-2-PENTANONE, 4-	Non-haz?,M										
72	METHYLENE CHLORIDE	I	4.74E-10		1.05E-06				2.18E-07			
73	METHYLNAPHTHALENE, 2-	Unclass?,M							1.05E-05			
74	NICKEL	M			4.80E-02	4.28E-03	1.38E-02	1.23E-03			5.82E-03	5.18E-04
75	NITRATE	M			1.12E-01				1.52E-03			
76	PHENANTHRENE	M			1.48E-03				3.75E-04			
77	POTASSIUM	Bkg,M,EPA-10										
78	PYRENE	M			4.40E-03				3.00E-04			
79	SELENIUM	M			5.95E-03		8.40E-03		1.68E-03			
80	SILVER	Bkg,M										
81	SILVER CHLORIDE	M			1.79E+00							
82	SODIUM	Bkg,M,EPA-10										
83	STRONTIUM	M			2.66E-04						3.35E-06	
84	STRONTIUM CHLORIDE	M			3.98E-09						5.00E-11	
85	SULFATE (SULFUR)	M			5.50E-05						1.64E-05	
86	TITANIUM (a)	Bkg,M										
87	TOLUENE	M			2.12E-03				5.83E-03			
88	TOTAL PETROLEUM HYDROCARBONS											
89	VANADIUM	Bkg,M										
90	XYLENE	M			5.67E-02						4.50E-03	
91	ZINC	M			1.01E-01	1.30E-01	2.81E-02	3.61E-02	7.19E-01	9.23E-01		
92	ZIRCONIUM (a)	Bkg,M										

(a) Concentrations of these chemicals fall within their respectively occurring background levels.

Table C.3. Results for Groundwater Away from the Columbia River

Name of Analyte	Notes	Carcinogenic Risk Ranking	Hazard Index Ranking	WQC Screen Ranking	LC50/100 Screen Ranking	TLM Screen Ranking
100 Areas						
Chromium (+6)	I	5.31E-02	1.30E-03	1.43E-01	1.57E-01	
Nitrate	M		4.77E+01		6.50E-01	
Strontium-90		3.62E-07				
Tritium (Hydrogen-3)		5.16E-09				
200 West Area						
Arsenic	I	1.82E-05	3.47E-02	1.26E-04	2.18E-03	
Carbon Tetrachloride	M	5.37E-04	5.90E+00		5.25E-03	
Chloroform	I	4.16E-06	6.93E-02		1.60E-03	
Chromium	I	1.09E-02	2.67E-04	2.94E-02	3.23E-02	
Fluoride	M		1.38E-02			4.38E-03
Iodine-129		2.71E-08				
Nitrate	M		4.85E+02		6.61E+00	
Technetium-99		9.13E-08				
Trichloroethylene	M	3.02E-08			5.82E-05	
Tritium (Hydrogen-3)		4.00E-07				
Uranium		1.61E-07				
200 East Area						
Arsenic	I	1.82E-05	3.47E-02	1.26E-04	2.18E-03	
Cesium-137		2.73E-04				
Chloroform	I	1.82E-08	3.04E-04		7.00E-06	
Chromium	I	9.75E-03	2.38E-04	2.62E-02	2.88E-02	
Cobalt-60		3.79E-04				
Cyanide	M		1.95E-03	1.72E-01		
Iodine-129		1.81E-08				
Nitrate	M		1.46E+02		1.99E+00	
Plutonium-239/240						
Strontium-90		1.04E-06				
Technetium-99		7.61E-08				
Tritium (Hydrogen-3)		2.66E-07				
Uranium		2.69E-09				
600 Area (Solid Waste Landfill Site)						
Chloroform	I	1.30E-09	2.17E-05		5.00E-07	
Dichloroethane, 1, 1-	M		4.92E-06		3.18E-06	
Tetrachloroethene	M	2.66E-07	5.21E-04		9.23E-05	
Trichloroethane, 1, 1, 1-	M	5.60E-07	2.44E-03		1.00E-04	
Trichloroethene	M	1.90E-08			1.27E-05	

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